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REVIEW OF WORLD AVIATION

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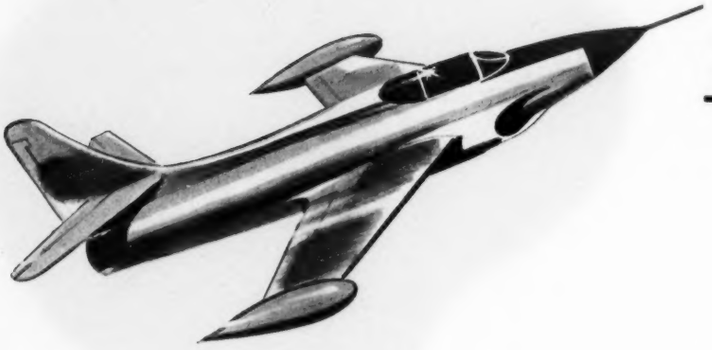
ATOMIC ENERGY

VOLUME VI 5 1951

America's Jets Demand the Finest



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INTERAVIA

Review of World Aviation

Volume VI No 5 1951

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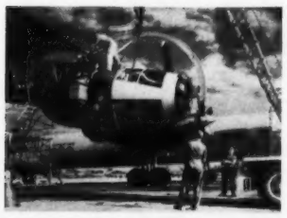

Front cover :

Fitting a Pratt & Whitney R-4360 "Wasp Major" engine in a Boeing B-36 long-range bomber. The B-36 "Wasp Majors" drive Curtiss Electric three-bladed pusher propellers 19 ft. in diameter.

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UNITED AIRGRAM

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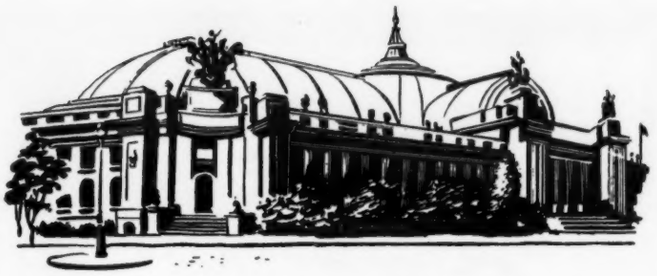
Dear Sir:

The aircraft world is looking forward with interest to the 19th Salon International de l'Aeronautique, which will take place in Paris during the last half of June. In view of the traditional role of France as a pioneer in all aspects of aviation and the great importance of her contributions thereto, the forthcoming exhibition will attract wide attention.

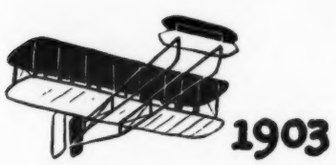
The exhibition will be held simultaneously in the Grand Palais on the Champs Elysees and at Le Bourget Airport. In the Grand Palais will be exhibited light and medium-weight aircraft, also engines, accessories, ground equipment and machine tools of France and other countries; and airlines will have booths and displays. At Le Bourget Airport will be shown those aircraft which are too large to be exhibited at the Grand Palais.

United Aircraft Export Corporation will have representatives at the Salon and all four manufacturing divisions of United Aircraft Corporation - Pratt & Whitney Aircraft, Hamilton Standard, Sikorsky Aircraft and Chance Vought Aircraft - will participate. There will be some especially interesting exhibits, including (1) a cutaway Pratt & Whitney Wasp Major engine — a 3,800 horsepower giant which is the most powerful piston engine in the world, and now powers such intercontinental bombers as the Consolidated B-36, the Boeing B-50, as well as such cargo carriers as the Douglas C-124 Globemaster, the Boeing C-97 Stratofreighter, the Boeing Stratocruiser Airliner, and other big aircraft; (2) a cutaway Double Wasp - one of the most widley used engines in the world for both military and commercial aircraft. During World War II the Double Wasp powered such memorable fighters as the Republic P-47 Thunderbolt, the Vought F4U Corsair and the Grumman F6F Hellcat; (3) a model Chance Vought Corsair airplane - the only fighter of the last war of such advanced design as to warrant continued, uninterupted production, and the only propeller driven fighter now being produced in America; (4) a model of a Sikorsky S-55 helicopter - which has been ordered in increasing numbers for use by all branches of the U. S. Armed Forces. The S-55 succeeded the S-51 which is performing so brilliantly today in the Korean conflict not only in liaison, rescue, spotting and supply assignments, but also as an effective plane-guard for aircraft carriers of the U. S. Navy; (5) Hamilton Standard, in addition to showing the latest development in propellers, will display the newest cockpit air conditioning

unit used in high-speed jets. This unit takes in 240 cubic feet of air every minute at a temperature of 600 degrees F. and delivers it to the cockpit at just below freezing point. The best measure of the performance of this unit is its ready acceptance by the aircraft industry, and the fact that production orders have already been received for its installation in three of America's top jet fighters; (6) engine vibration equipment manufactured under Pratt & Whitney Aircraft license by MB Manufacturing Company, Inc., also, special Hamilton Standard propeller tools manufactured by Kell-Strom Tool Company, Inc. We are happy to have this opportunity to display our products and all those who attend the Salon are invited to visit our exhibits, which will be centrally located on the Main Floor of the Grand Palais.



The French aeronautical and air transport industries will be well represented and we are deeply gratified that our own engines and propellers will play such a liberal part, through installation in some French-built aircraft.



The first Salon International de l'Aeronautique was held in Paris in 1908 and the succeeding exhibits have chronicled the achievements of the world, and particularly France, in the field of aeronautics. When we consider that the scientists and engineers of France have always taken a progressive and farsighted attitude in aviation, and that they have repeatedly shown remarkable imagination, skill and courage in aeronautical construction and in flight technology, it is indeed appropriate that a display of world-wide scope should be given in Paris.

When it is considered that less than six years have elapsed since the ending of the Second World War, with its devastating effect upon all French industry, the world must pay tribute to France and her aircraft and airline leaders for the extraordinary strides made in aviation during a time when profound readjustments had to be made in the nation's war-displaced economy.

All those who are interested in man's progress in flying have been invited to view not only the results of French achievements in this field, but also the aeronautical products of other countries, including those of the United States. With the yearly growth in travel to France, it is expected that the Salon will receive enthusiastic patronage.

To the management of the 19th Salon International de l'Aeronautique we extend every good wish for an outstanding success.

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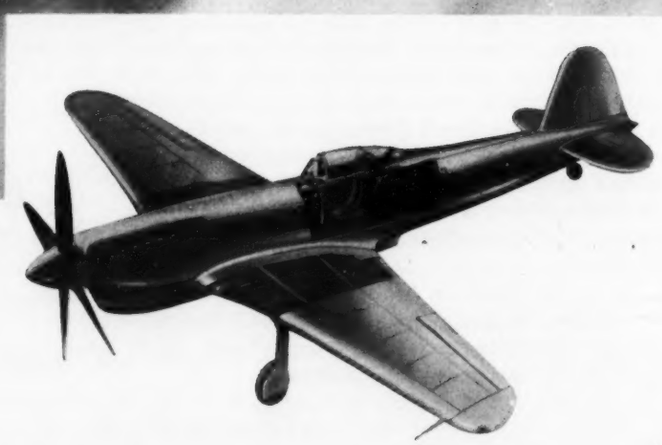

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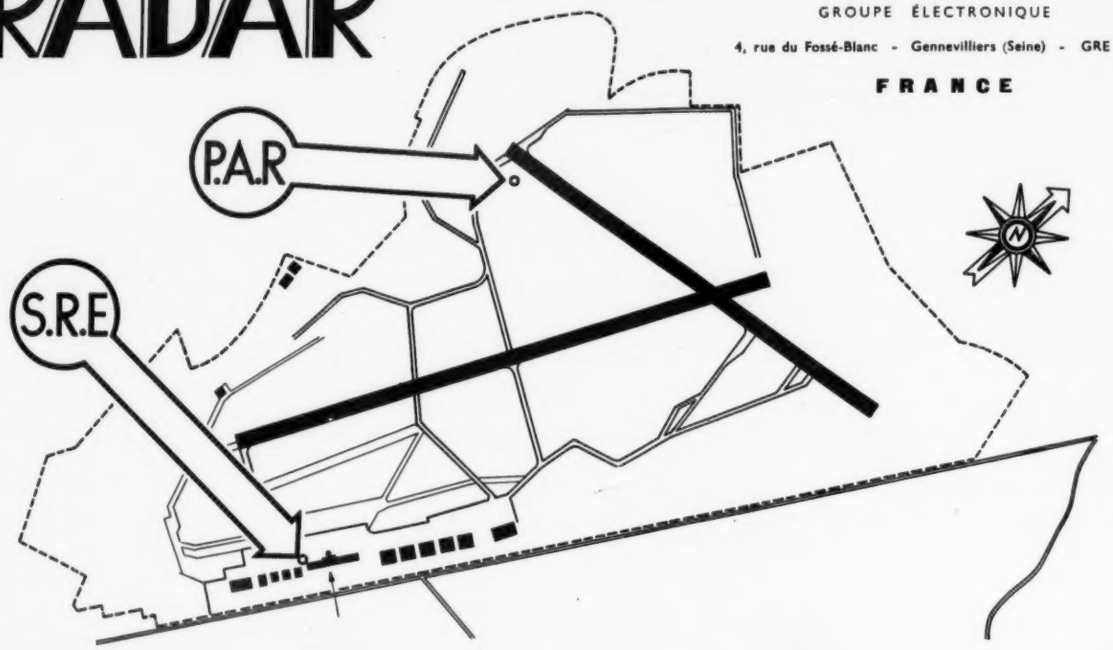

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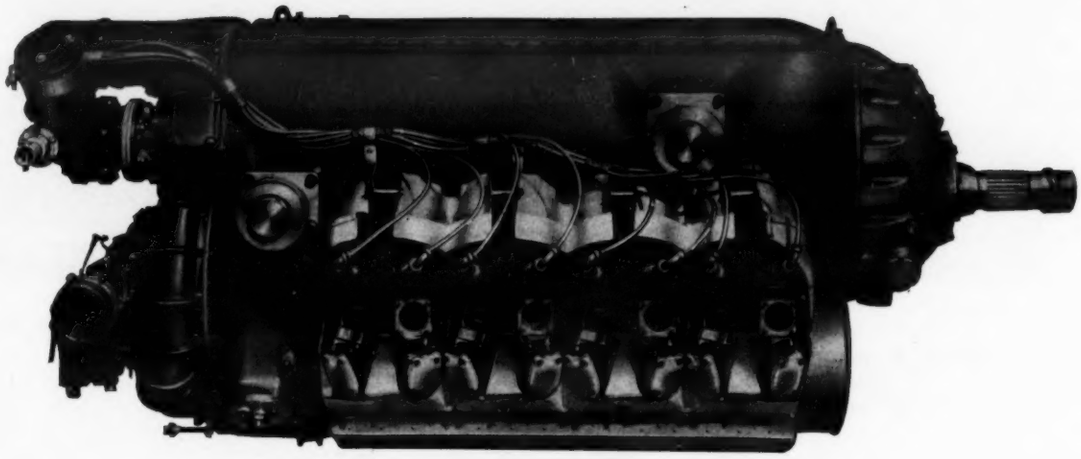

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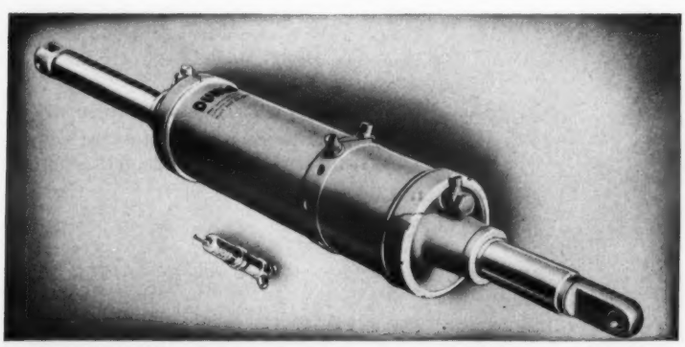

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Atoms Are Ancient

The atom has been a subject of discussion and study since time immemorial. Hindu philosophers living hundreds of years before the birth of ancient Greece had established a broad concept of the atomic structure of matter. In the fifth century B.C., Leucipus and his pupil Democritus became the founders of the Greek school of atomists. Democritus named the smallest indivisible unit of matter *atoma*—a composite word derived from *à* and *temnein (i.e.*, "not" and "to cut," in other words, something which is so small that it cannot be divided). Five hundred years later the Roman Lucretius again expounded atomism in his famous poem, "*De Rerum Natura.*" He conceived a theory according to which hard matter consisted of atoms held together by hooks.

Interest in the atom was revived in the period following the Renaissance in Europe, and in the Nineteenth Century speculation gradually turned into serious study and research. Tremendous progress in the discovery of the nature of the atomic structure of matter and its electrical properties has been made in the last 80 years, and the most spectacular results have been obtained in the past twenty years.

We all learned at secondary school that the atom was the smallest unit, the ultimate end. We, laymen in the matter, have been taught differently since 1945. The fact that the atom can be split today is one of the world's significant forces, for good or evil.

The Editors of *Interavia* have been gratified to note from numerous readers' letters that men and women of today are immensely curious about the thing, the atom, which is exerting such a tremendous influence on their lives. They became convinced that they would render their readers a service by asking an eminent atomic scientist to explain, as simply as possible in view of the complexity of the subject, how it comes that the atom can wield such awful power. Professor Friedrich Dessauer, of Fribourg University, Switzerland, undertook the assignment, and his article is published in the following pages.

No *instructive, scientifically acceptable* story on atomic energy will provide easy reading, in view of the vast complexity of the problem. Professor Dessauer's article will require *careful* attention and a little concentration, but the result will be well worth while.

Other articles in this issue deal with the future application of atomic energy to aircraft propulsion, the progress that is being made in the development of aircraft as intercontinental atom-bombers —and, ultimately, atom-driven bombers—and the protection that is available to the simple citizen in the event of a catastrophic World War III. We now pass the word to the Mighty Atom.

THE EDITORS.

The Production of Energy from Atomic Nuclei

BY PROF. FRIEDRICH DESSAUER, FRIBOURG

It is just twelve years since Otto Hahn and F. Strassmann discovered how to split the uranium nucleus and in so doing to release an amount of energy formerly unknown. Today this discovery and its consequences have become the background to international politics. The day-to-day struggle between the statesmen of East and West can only be understood against this background. Winston Churchill's statements in the House of Commons in August, 1945, that mankind had come into possession of a power which nothing could resist and that the atom bomb had brought us peace, but only man could keep that peace, reflect the atmosphere of these days and years.

What at one time was realised only by a relatively small number of people, namely that scientific research makes world history, has now become clear to all.

The political power which this scientific discovery has introduced into the history of mankind represents, however, only *one* aspect of the situation. Another aspect, still vaster, comes to light when we consider the potential effects of the discovery on our civilisation. This new source of energy, which has been recognized as the source of the energy of the sun and the fixed stars, is finding its way into allied spheres and into engineering. In research—including biological research—it is already playing an important part. Within the near future it will have a greater and greater influence on industrial power supplies, not only where large power stations are concerned but also, as can already be foreseen, in mobile energy producers, *i.e.* in large ships and aircraft. The less obvious, though no less important, results of the investigation of atom nuclei which entered a new stage with Hahn's discovery (that is the investigation of the material structure of the world), are not to be discussed here. The importance of the subject from the point of view of politics and in particular of power supplies—among other things in aviation—is tremendous.

PHYSICAL PRINCIPLES

The 92 atoms which were found to be the physical building stones of the earth resisted all attacks in chemistry and in classical physics. Whatever hap-

Born at Aschaffenburg on 19th July 1881, the author, fired by Röntgen's discoveries, devoted himself from an early age to radiology and the physics of radiation. Scars from over 100 operations still testify to the burns to which scientists were exposed, almost without protection, in the pioneering days. Professor Dessauer built a great deal of medical X-ray apparatus and produced the first transformers for very high voltages. From 1920 to 1933 he held the chair of Medical Physics at the Goethe University, Frankfurt-am-Main, then was invited to the chair of radiology and biophysics at the University of Istanbul. Since 1937 he has been Professor of Experimental Physics at the University of Fribourg, Switzerland. He has given guest lectures at American, Dutch and Spanish Universities and enjoys a firmly established reputation in present-day physics. His scientific (and philosophical) works—Philosophie der Technik—Wilhelm C. Röntgen—Der Fall Galilei und wir—A biography of Newton—Weltfahrt der Erkenntnis—Atomenergie und Atombombe—etc., have been translated into several languages. —ED.

Prof. Otto Hahn, Director of the Kaiser Wilhelm Institute for Chemistry, Berlin, discovered the fission of the uranium atom. Nobel Prize in 1946.

pened, they remained unchanged.—They therefore proved to be *solid*. However, as it was found at the turn of the century (following the discovery of radioactivity) that atoms are not simple homogeneous basic building stones, but complex, so to speak fine-structured *systems*, it was necessarily concluded that these natural atoms are solid, more or less compact, stable structures. When is a structure resistant to this extent, so proof against attack? An example will suffice to show that an important condition of stability may be *lack* of energy in its structure. An explosive for example is unstable. It is charged with chemical energy, and all that is needed is a primary impetus, an "initial ignition," for it to destroy itself through the release of the energy contained in its structure. However, substances arising as the final products of the process known as "explosion," are very stable—they no longer contain any considerable quantities of energy in their structure. For example they cannot be "burned" (oxidized) further. There is, so to speak, "nothing more in them."

Structural, like chemical energy, is described as potential energy. In our cases it is an energy of configuration of the *position of the particles* in relation to each other in their fields of forces. In the explosion given above as an example they convert themselves into less tense, more stable and balanced situations. In this process the energy that was formerly "carried," or potential, is released. It emerges as heat, as radiation energy, as kinetic energy—such are the phenomena which accompany the transition to more stable conditions.

It is a general characteristic of natural law that supplies of potential energy, stores of work potential, seek to convert themselves into other forms of energy, the energy being dispersed in the process. This is due to *entropy*, the *tendency to expand and reduce intensity*. Every amount of energy has a qualitative and a quantitative factor. In the case of heat energy, for example, temperature can be described as the qualitative (intensive) factor and heat capacity as the quantitative (extensive) factor. Everyone knows by experience that a hot object, such as a vessel of hot water, "cools down" by warming up its surroundings. Its heat energy is dispersed in that other objects in the neighbourhood take over heat energy from the warmer system; dissemination of the heat is increased at the expense of temperature.

The law of entropy states that this natural process cannot be reversed "by itself," that energy, once dispersed, does not return of its own accord. Admittedly the initial energy can be returned to the original system by artificial means, but this involves additional expenditure (of energy). In other words, the condition of the dispersed energy is more probable, and therefore more persistent, than that of stored-up energy.

Applied to the atomic nucleus this means that atoms are "systems" which are the more stable the *less* potential energy (of configuration) there is stored up in them. Atoms of medium atomic numbers have a balanced stable structure. From about atomic number 20 to about 83, *i.e.* in the centre of the periodic system, their content of internal (potential) energy is relatively small. On the other hand the elements with high atomic numbers—over 83 up to 92 (uranium) and the elements with low atomic numbers, such as lithium (3), beryllium (4), boron (5) are over-charged with energy in their structure, and therefore have a tendency, in principle, to rearrange themselves and give off their surplus energy. This means, however, that heavy atoms (with high atomic numbers) become transformed in certain conditions into atoms of medium atomic number, *i.e.* split up into two or three atoms of greater stability—a process similar to an explosion. This is what Strassmann and Hahn discovered. But in the case of the light atoms, which are also striving towards greater stability, this can only be achieved if several of them combine to form a nucleus of medium atomic number. This too is possible.

In both cases, *i.e.* of the splitting of heavy nuclei and the fusion of light ones, the more stable state—the formation of nuclei of medium atomic number—is reached through intermediate stages which are frequently very complicated. In both cases energy is released. And it is here that the great discovery of F. Hasenörl (Vienna 1904) and Albert Einstein (1905) comes in as a signpost to research: *mass, i.e. that which has weight and is "inert," represents a special form of energy*. In addition to kinetic energy, heat, electrical energy, radiation energy, or the old forms of energy each of which can be converted into the others, there is the new form "mass" (matter, material), which can also be transformed into other forms. Thus when a system —for example, a heavy atom—releases energy on fission, the final products of the fission must be smaller in mass, *i.e.* lighter than the original atom with its overcharge of energy. The reduction in mass (and weight) must correspond exactly to the energy released. The same must be the case when light atoms combine to form medium ones.

What is the mass of energy—or to put it in a more popular though equally correct form, *how much does energy weigh?* A. Einstein found the magic formula for this in 1905: mass (m: expressed in grams) equals energy (E: expressed in ergs) when a conversation factor is added. This factor is the speed of light in a vacuum (c; in cm per second) squared. That is, $mc^2 = E$ or $E/c^2 = m$.

If there is a loss of mass of *1 gram* in the atom bomb or in the industrial conversion of fissionable matter, 900 trillion* ergs of energy are released[1]. That is, about 34 million horsepower-hours or 25 million kilowatt-hours—the daily output of the power stations of a small state.

We now ask: What does it mean to the individual atoms that the conversion of one gram of energy in the form of mass provides over 30 million horsepower-hours of energy in the form of heat, radiation or motion? One gram of uranium U 235 contains about 2600 trillion atoms. Thus the share of each atom in the energy released is roughly $^1/_3$ erg. If the whole gram were radiated in free energy, this is the amount of energy which would be produced from each atom of U 235. However, in the splitting of U 235 into, as a rule, two more stable, medium-heavy atoms only about one thousandth of the weight is transmitted in released energy, *i.e.* not $^1/_3$, but about 1/3000 erg. Such a quantity cannot be clearly pictured. Instead of the units of energy hitherto used (erg, kilowatt-hours, horsepower-hours) we shall therefore introduce the appropriate unit of energy, the "*electron volt*" (eV), which is normally used in nuclear physics. *The product of the elementary charge* (charge of the electron) *and the voltage of one Volt, an electron Volt is equal to 1.59 billionths of an erg.* One erg therefore equals 626,000 million electron volts[2]. When a U 235 atom is split the 3000th part of it, *i.e.* 210 million electron volts or 210 MeV (Mega electron volts) is released.

This can be compared with known values. In a chemical reaction which releases energy, such as combustion, 0.1 to about 10 eV can be released per molecule. The "reaction heat" of a single U-fission provides ten million times more energy. The specific energy released, *i.e.* the amount released per unit (1 atom, 1 molecule), is therefore of a quite different magnitude.

It might well be thought that formations which were so over-charged with structural energy would react spontaneously—or through some slight outside influence (ignition)—like chemically explosive substances. This is indeed true of the naturally radioactive elements which spontaneously transform themselves, through giving off energy (α, β, γ radiation), into more stable elements, and finally all turn into lead. But most of them do this slowly, and spontaneous fusion is unknown among the lightest elements. The very fact that the 92 natural elements are still found on the earth, which has existed in its present phase of development for at least 3000 million years, shows that atoms, including the heavy and the light ones, naturally have a relatively stable structure—in spite of the sometimes high potential energy of this structure. We began with the statement that the 92 atoms survive all chemical reactions without change. Man therefore had to discover special "ignition processes" before structural changes with attendant release of energy could be initiated.

These initiating processes, which so to speak set the avalanche of the energy release in motion, are different for the fission of atom nuclei and for their fusion. The physics and technique of atomic fission based directly on Hahn's discovery use heavy atoms, in particular uranium and plutonium, and the well-known piles are built out of highly purified basic materials. It was on fission that were based the early experiments in the solitude of the New Mexican desert (16th July, 1945), the bombs dropped over Hiroshima and Nagasaki, which ended the Japanese War at one blow, and the Bikini tests.—The other way, *i.e.* freeing and utilizing

* Billion, trillion etc. are used throughout in their European sense; i.e. a billion = 1,000,000,000,000; a trillion = 1,000,000,000,000,000,000.

[1] As the speed of light in a vacuum is $3 \cdot 10^{10}$ cm/sec, a gram-mass corresponds to an energy of $1 \cdot 9 \cdot 10^{20}$ g cm^2 sec^{-2}, i.e. 900 trillion ergs.

[2]) 1 eV = $1.59 \cdot 10^{-12}$ erg; 1 erg = $6.29 \cdot 10^{11}$ eV = $6.29 \cdot 10^6$ MeV.

captive energy, starts from the lightest atoms. It is more recent in date, not yet so far advanced, and has become known to the public under the name "hydrogen bomb."

MODEL OF THE ATOMIC NUCLEUS

It is not often remembered that a scientist who seeks to penetrate unexplored regions in nature can only start out from what is already known and explored. Necessarily he must operate with ideas and concepts with which he is already familiar, and which thus grow out of what has already been investigated. But he can never be sure that his ideas and concepts will suit the new territory. Quite frequently in the history of scientific research they have not been suitable. For example it was found to be impossible to describe the processes of electricity and light through the ideas and concepts of mechanics, *i.e.* to base electro-dynamics entirely on mechanics, on Newton's laws.

The scientist finds himself in just such a situation *vis-à-vis* nuclear physics. Conditions are obviously different here than in those realms of physics which are already familiar. But the only solution is to press on with the existing methods of thinking and calculating—in the hope that after all there are certain relationships between the old and the new which will make it possible to get a foothold and then by adaptation to advance step by step. This is done with the aid of models. The models are frequently very rough at first—but are progressively adapted to the facts. A famous example is the "scale model" of the atom casing. Conceived by N. Bohr, further refined by him and by his pupils, but chiefly by A. Sommerfeld and his school, it provided a steadily improving, but never quite satisfactory, picture of the chemical and optical processes on the periphery of the atom. Now we must try to get a picture, a model, of the conditions and processes in the *atomic nucleus*. This nucleus is still mysterious—but the model has already advanced so far that it not only provides approximately accurate pictures but also that calculations and successful experiments can be based on it.

This nuclear model, suggested by the Russian physicist Gamov in 1930, is a *drop of liquid*. In the drop, *i.e.* for example, in a slow dripping out of a vessel, or in rain, a special configuration of the fluid is formed, which tends towards the globular. Very small and very large drops are not stable. But a drop of a certain size can be very resistant. This is due to a balance between the forces which tend to hold its particles together and those which tend to drive them apart.

The forces acting between the H_2O molecules of a drop of water are forces of cohesion, in the category of *van der Waals forces*. They are very great, but they act only over minute distances—hundred-thousandths of a centimetre—a distance which in everyday language can be called "close contact." When this distance is exceeded they break down. To snatch a water molecule out of this close bundle about 0.4 electron volts are needed. This is no small quantity for such small particles.

The other group of forces is based on the *heat movement* of the molecules. The drop has a temperature. Temperature is an everyday expression whose physical significance is closely connected with the speed of the (constantly moving) molecules of fluid. (To put it more exactly: temperature corresponds to the square of the mean velocity of the molecules). Because of this movement molecules are constantly flying off the surface of the fluid out of the range of the van der Waals forces into the atmosphere. This is what is generally known as vaporisation.

The battlefield of the opposing forces is the *surface* of the drop. The van der Waals forces draw the molecules inwards. At the surface, however, the attraction is from one side only: this gives a zone of reduced binding energy. The forces of cohesion directed inwards can be compared with the forces of an inflated rubber bladder, such as a football. The bladder "contains" the gas space inside which there is an excess of air pressure, and there is a "surface tension." The same happens in the drop. The forces of cohesion cause the surface of the drop to behave like a taut elastic skin holding the drop together.

As temperature rises the molecules are more and more driven outwards, vaporised; as temperature falls the drop becomes more stable. Its fate is decided at the surface where the force holding together the molecules is one-sided and therefore weakened, not "saturated."

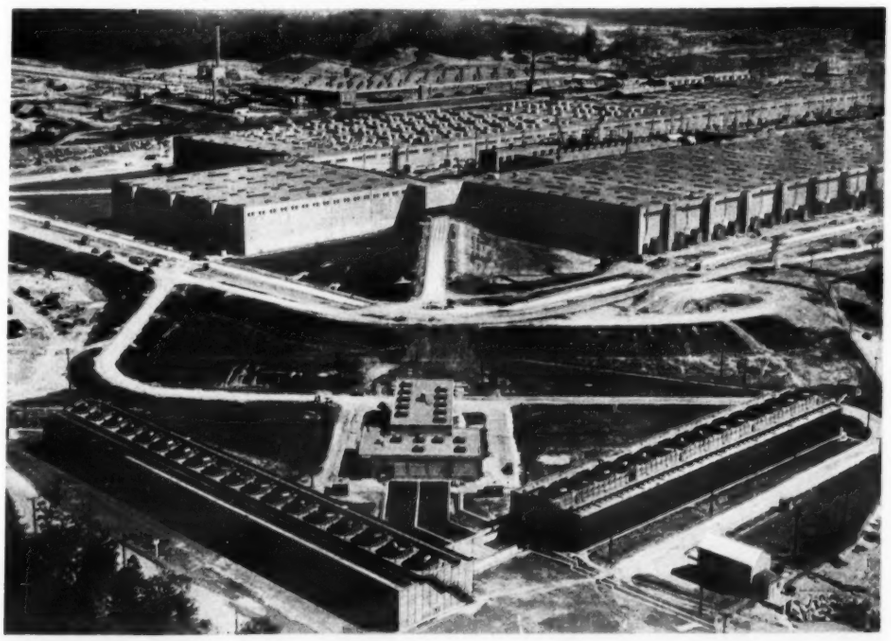
Now for the analogy with the atomic nucleus. The latter is built up of two kinds of nuclear particles, "nucleons," which are known as *protons* and *neutrons*. The proton appears singly, as the nucleus of the hydrogen atom, and has a single positive charge. The neutron has no charge. The word "particle" must be used with caution. The nucleons are quite different from a macrophysical body. Only with this reservation may we speak of their size, their diameter, which is in the region of tenths of billionths of a centimetre (10^{-13} cm). However, we may justifiably talk of their mass, which is slightly larger in the neutron than in the proton, though in both cases it is of the order of quadrillionths of a gram (10^{-24} g). One can be converted into the other: on conversion into a proton the slightly heavier neutron therefore gives off mass, in the form of energy, and a negative electron. The mass lost corresponds to an energy released of approximately ¾ million electron volts. The neutron is therefore radioactive—it tends to become a proton by emitting an electron and releasing energy (into which we need go no further here). On the other hand energy must be added to convert a proton into a neutron and compel it to radiate a single positive charge, a "positron."

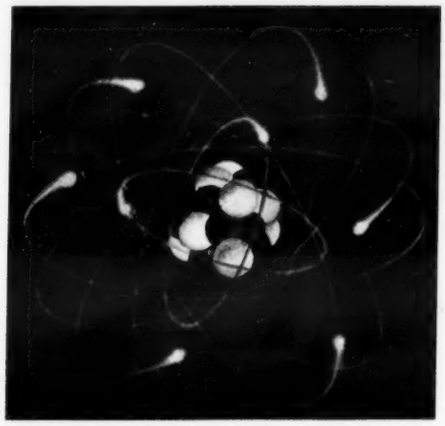
Between the nucleons in the nucleus (protons *and* neutrons) there are *forces acting over a very short distance*—analogous to the van der Waals forces of cohesion between the molecules of a fluid. But they are incomparably stronger. The work required to separate them is not 0.4 electron volts, but 1 to 8 million electron volts. This means that the forces of cohesion between neighbouring nucleons are vastly more powerful than anything physics has hitherto known in the way of particle forces, and in this fact lies the greatest secret of atomic structure which in spite of all efforts has not yet been penetrated. The secret becomes even more mysterious, so to speak, when it is realised that these nuclear forces, unlike the molecular forces, act not over a distance of hundred thousandths of a centimetre but over a distance which is ten million times smaller, *i.e.* billionths of a centimetre. This is the first analogy of the model.

The dispersive, vaporizing forces of heat have their analogy in the *repellant forces of the positively-charged protons*. In hydrogen there is only one proton, in helium two—in every atom as many as indicated by its "atomic number," so that uranium has 92. The repellant force ("Coulomb force" of the positively-charged protons) is in inverse ratio to the square of the distance. The nuclei are packed tight with nucleons by the tremendous nuclear forces.—The nucleus may roughly be regarded as a small sphere which has a radius measured in billionths of a centimetre (10^{-12} cm).—Consequently the explosive internal forces increase enormously with the number of protons and reach such a magnitude in the heavy atoms that all atoms with more than 82 protons (bismuth) are radioactive, that is they are unstable because of their excessive internal energy, and they decay spontaneously.

The third analogy with the drop of water is in the importance of the surface. *In the nucleus too cohesion at the surface is one-sided and therefore not saturated.* Here therefore a nucleon can "eva-

Aerial photograph of part of the Clinton Engineer Works at Oak Ridge (Tennessee), where the separation of the fissionable uranium isotope U 235 is carried out mainly by gas diffusion.





Scale model of an oxygen atom (outside) and drop model of a nucleus (inside). The oxygen atom has the mass number 16, its nucleus is composed of 8 neutrons (uncharged) and 8 protons (positive unit charge). Consequently each atom has 8 electrons (negative unit charge) which are represented as distributed round the nucleus in several different shells. All 16 nuclear particles are shown here as "visible."

porate off," like molecules of water from the surface of the drop. But the reverse also is true: if a water molecule from the atmosphere comes within a hundred thousandth of a centimetre of the surface of the drop it can be caught up by the van der Waals forces: and if a neutron or proton from outside comes to within a billionth of a centimetre of the surface of the nucleus it is captured by the non-saturated binding forces at the surface. In both cases condition, structure and equilibrium are changed through the addition or the loss. A new situation arises—something happens. This is the "event" which comprised Hahn and Strassmann's original discovery: when a "slow" neutron is captured by the surface of a U 235 nucleus [3], the latter's structure is so shaken that it begins to vibrate and the tremendous Coulomb forces of the 92 tightly packed protons split it.

The conditions of equilibrium inside the nuclear structure and concepts of this structure in the battle between the binding forces in the nucleus and the dispersive (and better known) Coulomb forces still present the scientist with great difficulties, which must be overcome step by step. Nevertheless it now seems probable that here too a "scale concept" (as for the periphery of the atom) will prove valuable as a model, whilst on the other hand, for example, it is certain that the helium nucleus ($_2He^4$), formed of 4 particles (2 protons and 2 neutrons), has a "*crystalline*," extremely stable, structure which, however, is weak in potential energy.

The sum of the individual masses of the four nucleons is considerably greater than the total mass of the helium nucleus formed by them. The mass deficiency of about 30 MeV is therefore radiated when they combine—a very productive energy-releasing reaction. It is the prototype of what happens in the fixed stars (such as our sun), (though in a much more complicated way than by simple combination) and forms the source of fixed star radiation: fusion of lighter hydrogen nuclei (protons) into a heavier nucleus by absorption of neutrons. This produces a more stable structure, *i.e.* one with lower structural energy, which corresponds to the second line of research which has become known to the public as the "hydrogen bomb." In other words, the group of four nucleons in helium is found to be a group of heavily saturated binding forces. More than 30 MeV would be needed to separate them.

For our purpose the following simple considerations suffice :

1. Light atoms have few nucleons inside them. A relatively large number of nucleons lie on the surface and are therefore held only on one side. The critical zone of the surface is large in comparison with the internal volume. They are therefore relatively less stable; the capture of a proton or neutron from outside must affect their structure more powerfully.
2. When we reach higher atomic numbers in the table of the periodic system of the elements, there is an increase in the number of protons, *i.e.* in the "explosive charge" through Coulomb forces. This is compensated by the fact that atoms of medium and high atomic numbers have an increasing excess of neutrons: helium has the same number of neutrons as protons: iron has 26 protons but 56 neucleons, *i.e.* 4 extra neutrons; uranium 238 (the most common isotope of uranium) has a total of 238 nucleons, only 92 of which are protons, so that it has a large excess of 54 neutrons. They are included so as to produce a certain stability in the nucleus, overloaded with Coulomb forces, of the heaviest natural atom. In spite of this it is radioactive—decays spontaneously, though very slowly.

The cause of reduced stability in light atoms lies in their relatively large surface (non-saturated nucleons) and in heavy atoms in their high number of protons. At both ends of the periodic system of the elements there is a tendency towards conversion into more stable structures with less potential energy and consequently less mass. When such conversions take place energy is released. The question is how to set them in motion *and* how much energy is released.

THE TWO METHODS OF RELEASING ENERGY

If, as already seen, we compare these nuclei, which are over-charged with structural energy, with explosives of a chemical nature, we should expect that some impetus, or "ignition" will be required to set the energy-releasing process going. Even chemical high explosives such as trinitrotoluol (TNT) or dynamite can remain unchanged for a long time if there is no initial ignition. In chemical explosives the energy for ignition is of the order of chemical reaction—for the individual molecule, of 0.1 to 1 electron volt. In nuclear processes, however, cohesion between the nucleons is millions of times greater than the chemical cohesion of the molecules. It is therefore to be expected that the amount of individual energy required for the "initial ignition" of a process of nuclear fission or nuclear fusion will be much greater than in chemistry. Otherwise it would not be possible for 92 natural elements to be in existence after 3,000 million earth years.

The energy for the *chemical* initial ignition can be supplied by a small local heating (a blow can produce an appreciable local heating). The energy-releasing reaction starts with a few molecules which have been heated up by perhaps several hundreds of degrees, and the heat energy released produces a similar reaction in neighbouring molecules—and so on. A *chain reaction* sets in, which in certain circumstances is completed within a small fraction of a second. In the explosive *nuclear* reactions based on fission *chain reactions* will again be needed to enable the initial ignition to propagate itself.

However, there is another possible method—general slow application of heat (increase in temperature) also causes chemical substances of high structural energy to "detonate." Their "energy level" has become too high. There is little need of an outside impetus if a store of dynamite, carelessly located, is uniformly heated up.—For nuclei this means that *at an energy level corresponding to many million degrees of temperature light nuclei cannot be stable, but must combine to form heavier ones.* This is what happens in the centre of the sun and smaller fixed stars, where "exothermic" nuclear fusions taking place at an energy level of 20 million degrees (and well over) form the source of energy radiation.

The analogy with the explosions of chemical substances can be taken a step further. The word explosion evokes a picture of particles being split wide apart. This is the *result* of the release of energy: on closer inspection the process takes on a different aspect.—An example: in the "explosive gas reaction," *i.e.* the combination of two parts of hydrogen gas with one part of oxygen a drop of water *is formed and* energy is released. This is therefore a "detonation" (release of energy) through combination, through the fusion of the partners. This corresponds diagrammatically to the processes taking place when light atoms join together to form heavier ones—the principle of the "hydrogen bomb."

ISOTOPE, COULOMB ENERGY AND BINDING ENERGY

Chemistry discovered and isolated the elements as 92 different types of atoms. This was done by chemical methods. These are bound up with the outermost "shells" of the atom's periphery, with the carriers of the co-called valence forces (chemical quantivalence of the elements). The number, nature and arrangement of these "shells" or electron casings are determined by the "nuclear charge number," that is, by the number of protons each with a positive electric charge (also the atomic number). Thus a term such as $_{92}U$ (uranium) or $_{90}Th$ (thorium) gives an indication only of the number of protons in the nucleus and their accompanying electron shells. It does not tell how many neutrons there are in the nucleus. This cannot be measured by chemical means, since neutrons do not react to chemical characteristics (or, more exactly, react only slightly and indirectly). But the content of neutrons, as shown in the preceding section, contributes towards the stability of the structure, its equilibrium, and tendency to regroup or split up and release or absorb energy.

Physically it was found that in practice there are variations in the number of neutrons in the majority of natural elements. For example there are three variants of uranium. The 92 protons may be accompanied by 146 or 143 or 142 neutrons, so that the total number of particles in the three types of uranium is $92+146=238$ or $92+143=235$ or, rarely 234. The natural element is always a mixture of these components and their ratio is always the same regardless of the place of origin and the compound. These components are also known as *isotopes* (occupying the same place—*i.e.* in the periodic system). They are chemically similar, therefore not separable by chemical means, but different in mass (particle or mass number) and therefore in principle separable by physical means. Consequently they differ widely in their energy and in nuclear reactions. In the case of uranium the

[3] In nuclear chemistry it is usual to give both the atomic number (protons) and the atomic weight (protons plus neutrons) : for the U 235 nucleus it is $_{92}U^{235}$, for the hydrogen nucleus $_1H^1$, for helium $_2He^4$, etc.

proportion of the isotope U 235 is only 7 per thousand, that of the isotope U 234 only 0.06 per thousand parts of any given quantity of uranium. The isotope U 238 is by far the most common—but Hahn's discovery was made with U 235. For it was this isotope which was so disturbed in its internal structure by capturing a "slow" neutron that the Coulomb forces split it with 200 million electron volts. In the early days it was *the* important material and the first tedious methods of separation were developed and *separation equipment* built to separate it from the preponderant U 238.

We must content ourselves here with this brief reference to the neutron's decisive influence on *nuclear* reactions, although comprehensive and successful studies of the influence of the particle numbers and configurations on nuclear stability are available (*e.g.* by J. Mattauch). The question of symmetry and of whether numbers of neutrons and protons are odd or even plays an important part.

That fission can occur if the nuclei—disturbed by capturing a neutron—are shaken out of the basically unstable equilibrium of their structure, is due to the unequal range of the opposing forces. *The Coulomb repulsive forces act over distances*, though they decrease with the square of the distance between the mutually repellant charges, *but the cohesive binding forces between the nucleons, being powerful close-range forces, are reduced steeply as distance increases*. If therefore asymmetry occurs (cf. diagram of the fission process), the Coulomb forces alone act, are no longer compensated by binding forces, and fission must take place.

We have thus collected together sufficient information to enable us to examine the curve of "*binding energy*" which, it will be readily understood, gives valuable indications of the two ways of releasing nuclear energy. This figure shows the particle numbers from 1 to 238 on the horizontal (*i.e.* the abscissa), *i.e.* from hydrogen to uranium. The ordinate gives the "binding energy per particle" in millions of electron volts (MeV). American publications call this a Bepp curve (*b*inding *e*nergy *p*er *p*article).

We already know that binding in the lightest atoms must be weaker because of the relative size of the surface of the "nuclear drop," and in the heavy atoms because of the counter-effect of the Coulomb forces. Binding energy is energy with a negative sign: it means stability, *deficiency* of potential structural energy. This may be expressed, perhaps more graphically, as: binding energy is that energy which must be expended to separate a nucleon from the nucleus (against the binding forces). The curve shows that nucleons in light nuclei are not so firmly held. A nuclear particle can be removed from light nuclei by 1 to 6 MeV; for the medium nuclei over 8 MeV are required. If therefore it were possible to combine very light nuclei, such as hydrogen, lithium, beryllium, to form slightly heavier ones, this would be one way of reducing the potential energy contained in the structure; a more stable structure with less internal tension would be formed, and the energy difference would be released.

The steepness of the curve shows that this possibility is attractive since the differences in Bepp energies released are large here. This is the way in which Nature—in the hot stars— releases energy by uniting nuclei and which is at the basis of the "hydrogen bomb." The end of the curve is less steep. But here, too, energy must be liberated if, for example, a uranium or thorium nucleus is converted by nuclear fission into two medium-heavy nuclei. This is the first way, based on Hahn's discovery, and developed in the U.S.A. during World War II.

Every means of releasing energy by fusion and fission has long since been extensively investigated in the laboratory. With present-day methods of producing very large individual energies in cyclotrons, synchrotrons and other mammoth apparatus, the equilibrium of any of the natural nuclei can be disturbed by bombarding them with neutrons, protons, alpha particles (helium nuclei), electrons of high kinetic energy or with photons (electro-magnetic gamma rays). The questions now are: what are the technical characteristics of the two processes: what expenditure do they require, what are the difficulties to be overcome and what are their prospects of providing useful sources of power.

OBTAINING ENERGY FROM FISSION PROCESSES

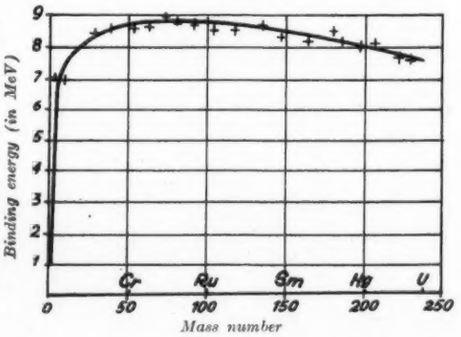
The relatively rare uranium isotope U 235 has three neutrons less than the principal isotope 238. It is less stable. A free neutron (these occur constantly through cosmic radiation) is "captured" by the nucleus of the isotope by the non-saturated binding forces of its surface, if it comes very close and *does not pass by too quickly*. The technical expression for this tendency toward condensation [4] of slow neutrons on to the surface of the nucleus is: great nuclear *cross section* for the capture of neutrons. The probability and hence the relative frequency of such capture is indicated in figures by the "nuclear cross section." The U 235 nucleus, as seen in the diagram, is disturbed by it. Its deformation leads to the splitting of the nucleus into two or, in rarer cases, into three, medium-heavy nuclei (via several intermediate stages). These nuclei are for instance, barium, strontium, xenon, caesium, rubidium. Krypton, tellurium, molybdenum, iodine, have also been found. The split nuclei are at first still very much over-charged with energy and hence radioactive. They cannot be in equilibrium as there are too many neutrons available. The great excess of neutrons in heavy nuclei, which amounts to no less than 51 in Uranium 235 (see above), as compared for example, with only 25 in stable barium, and 11 in krypton, is the cause of the powerful and *dangerous radioactivity* of the fission products after the detonation of atomic bombs. Only when further nuclear reactions, most of which are rapid though some are very slow, have taken place, is full stability achieved. But this excess of neutrons has another, very great significance. Following the fission two or three free, but fast, neutrons appear. When their speed has been reduced, these can be captured by neighbouring U 235 nuclei, where they may cause further fission. This, however, produces 4 to 9 more free neutrons. This process may lead to a chain reaction in the same way as the local initial ignition in the case of an explosive. It was the recognition of this fact that greatly excited physicists, firstly Frisch and L. Meitner, colleagues of O. Hahn's, after the discovery of fission, and that gave the impetus to the tremendous developments made in the U.S.A. during World War II, developments which led to the desired conclusion.

The important point here will be recognized immediately: the splitting of one or two atoms is of no value in practice. *A chain reaction can only occur if the fission neutrons are slow and really do hit U 235 nuclei.* Therefore the rare isotope U 235 must be separated out from the uranium, which, although purified, contains three components, and be built up into powerful concentrations. U 238 has a small capture section for slow neutrons and does not split afterwards. Hence the early attention to working out various methods of separation and the construction of tremendous refineries and separation plants to produce highly-purified uranium and subsequently concentrated U 235 (cf. picture of the Clinton Engineer Works at Oak Ridge).

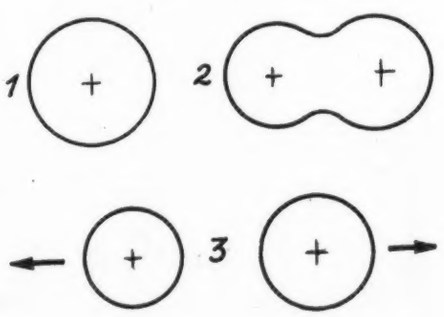
Another point is recognized: as the number of fission neutrons per individual process is small (according to recently released information 2.5 as a statistical mean), efforts must be made to prevent too many from being lost. Many substances absorb neutrons without anything particular happening. But highly-developed cleansing is not enough. Even in a spherical structure of highly concentrated U 235 only those neutrons which travel inwards can contribute to the chain reaction. Those that move outwards from the surface are lost. This means much in a small body (with relatively large surface). *There must therefore be a critical minimum volume of fissionable substance in which a sufficient number of neutrons remain inside.* Use was made of this in the atomic bombs. The U 235 mass (later also plutonium) was put into the bomb casing in *several fragments*, so that form and volume of each fragment

[4] Analogy in the model of the drop of water: the surface of the drop captures water molecules out of the air by van der Waals forces; condensation.

Binding energy per particle (in millions of electron volts) plotted against the mass number (number of particles in the atomic nuclei). The ordinate shows the energy that must be expended to remove a particle (proton or neutron) from the nucleus. The shape of the curve shows that the most stable nuclei are those with medium mass numbers. Energy is obtained from the lightest atomic nuclei (hydrogen, deuterium, tritium, helium, lithium) by nuclear fusion, and from the heaviest (thorium, uranium, plutonium), by nuclear fission.



In its basic state the uranium nucleus can be imagined as spherical (1). If excited by the addition of energy it may start vibrating, when it takes on the shape seen in (2). Then the Coulomb forces overcome the nuclear binding forces and split the nucleus (3).



alone were not sufficient for a chain reaction. The initial impetus is then given by a *very sudden* uniting of the fragments, produced by special means. This gives the volume, the internal contact and the correct form for the chain reaction. The actual processes —fission, emission of neutrons, their capture, new fission, etc.—all take place within microseconds.

The free neutrons appearing after the fission—some immediately, some with a certain delay—have high velocities. But only neutrons with low velocities lead to fission of U 235. Consequently a particularly important structural member of any installation for obtaining energy from fission processes is the "braking substance" or "moderator," which reduces the speed of the neutrons but does not capture them. Speed is reduced primarily through elastic collisions with atoms of similar or slightly greater mass than the neutron mass itself (according to the classic laws of collision). For this reason water, or better "heavy" water, helium gas and, hitherto most frequently (because of its availability) graphite of extreme purity (since impurities absorb neutrons) have been used (cf. diagram of chain reaction).

The true position is far more complicated. No brief description can give full details [5]. Gradually scientists succeeded in splitting *all* the heavy atoms, though some of them at such a cost as to make them of no value in practical use. U 238 can also be split (by fast neutrons) and adds to the effect of uranium piles. But in the first two bombs everything depended on the purity of the U 235 and the precision of the initial ignition. The possibilities of improvement are obvious. The smaller the loss of neutrons and the more sudden the union, the more effective the detonation. If purity is increased the quantities and volumes can be reduced in both bombs and

[5] Cf. F. Dessauer "Atomenergie und Atombombe," 2nd Edition (1947), published by Otto Walter, Olten, and "Atomic Energy for Military Purposes," the Official Report on the Development of the Atomic Bomb, by H. De Wolf Smyth, Princeton University Press 1947.

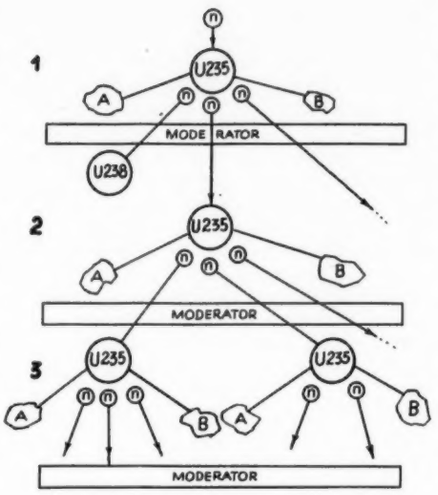


Diagram of a chain reaction through fission, using a moderator : nuclear reaction 1 is set off by a "wandering neutron" (n); nuclear reaction 2 by one of the (one to three) fast neutrons arising from the first fission; nuclear reaction 3 by two of the neutrons arising from the second fission and slowed down by the moderator, etc. Some neutrons are always lost, some hit on U 238 nuclei and convert them into plutonium nuclei (Pu 239). A and B are the split fragments of the U 235 nucleus.

energy production. Neutron-reflecting materials at the surface of the body can throw back a proportion of the neutrons.

For economic utilisation the chain reaction must be *controlled*. This can be done by means of neutron-absorbing substances which can be inserted to varying depths into the fissionable material and thus render a controllable proportion of the neutrons ineffective. For this purpose boron (boron steel) and cadmium are frequently used.

Meanwhile a new element, which does not exist in Nature, has been investigated by the physicists and used as a fission material. The common uranium isotope 238 captures neutrons of a certain, fairly high, speed range and stores them up in its nucleus. Since the atomic number remains unchanged at 92 (number of protons), this produces a new, artificial isotope $_{92}U^{239}$. This "intermediate nucleus" or "compound nucleus," however, is unstable, since it is overcharged with energy. To become more stable, a nuclear neutron changes into a nuclear proton, a process which is accomplished through the emission of an electron (beta ray) and the release of energy (mass deficiency). This has produced a new element with the atomic number 93 (93 protons), which has been named neptunium ($_{93}Np^{239}$). But this too is unstable, emits beta rays and gives rise to a further "transuranium" element known as *plutonium* ($_{94}Pu^{239}$) [6].

The important result of this procedure is the production of plutonium which, like U 235, can be split by "slow" neutrons. Its details are still secret, though doubtless more favourable than those of U 235.

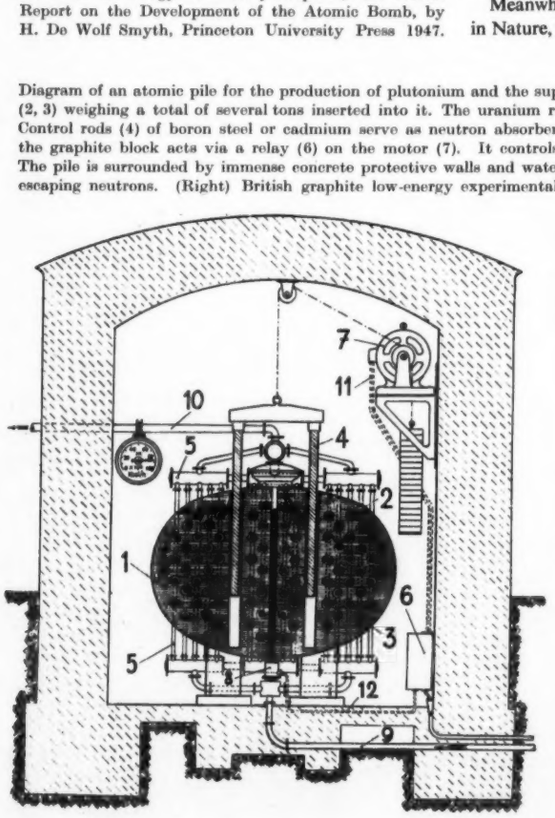
What is meant here by "slow," which is often replaced by "thermal" in scientific literature? Air molecules, *i.e.* principally nitrogen (N_2) and oxygen (O_2) have speeds of several hundred m/sec at normal temperatures. These are the "thermal" speeds. A free neutron which has not been specially accelerated has the same speeds. In many calculations they can be ignored and the particles treated as though they were at rest, compared with the tremendous speeds of the particles from cyclotrons or cosmic radiation.

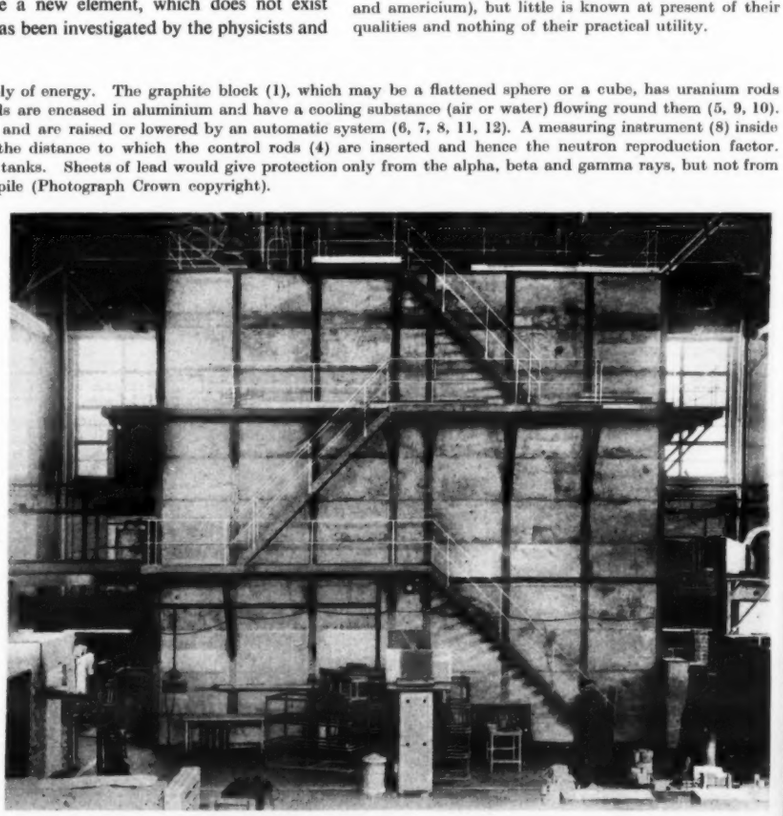
[6] In nuclear chemistry this process is written thus (the neutron being given the symbol $_0n^1$; no nuclear change, mass number 1) :—

$$_{92}U^{238} + {}_0n^1 = {}_{92}U^{239}; \; {}_{92}U^{239} \rightarrow B \rightarrow {}_{93}Np^{239};$$
$$_{93}Np^{239} \rightarrow B \; {}_{94}Pu^{239}$$

Physics has built up two more transuraniums (curium and americium), but little is known at present of their qualities and nothing of their practical utility.

Diagram of an atomic pile for the production of plutonium and the supply of energy. The graphite block (1), which may be a flattened sphere or a cube, has uranium rods (2, 3) weighing a total of several tons inserted into it. The uranium rods are encased in aluminium and have a cooling substance (air or water) flowing round them (5, 9, 10). Control rods (4) of boron steel or cadmium serve as neutron absorbers and are raised or lowered by an automatic system (6, 7, 8, 11, 12). A measuring instrument (8) inside the graphite block acts via a relay (6) on the motor (7). It controls the distance to which the control rods (4) are inserted and hence the neutron reproduction factor. The pile is surrounded by immense concrete protective walls and water tanks. Sheets of lead would give protection only from the alpha, beta and gamma rays, but not from escaping neutrons. (Right) British graphite low-energy experimental pile (Photograph Crown copyright).





We can now proceed to a description of the most important technical apparatus for the production of energy from fission, known as the "pile." In this apparatus a controlled fission chain reaction takes place. It therefore always has a centre of highly concentrated matter (U 235 or Pu). This releases energy—utilizable in the form of heat, in principle of any desired temperature. At the same time U 238 is converted into plutonium, and fission products, some of them highly radioactive, occur in the form of dispersing medium-heavy atoms, and a tremendous liberation of neutrons and gamma rays. These processes are naturally accompanied by ionization, chemical processes, corrosion, in brief by a multiplicity of complications. Because of the radiation the whole installation is highly dangerous, and therefore enclosed in outer casings of concrete and inner casings of cadmium (to capture neutrons) and thick lead (protection against gamma rays). The purer the fission materials in the pile, the smaller will be the "critical" volume of the unit; the more uranium oxide and thorium oxide are added, the bigger. The grid-like structure contains moderators to reduce the speed of the neutrons; dispersal or reflecting materials in the casing, to reduce the surface losses of neutrons; neutron absorbers (*e.g.* boron steel rods) with automatic regulation of depth of insertion; cooling systems to dispose of the heat energy (which may lead to the utilization of energy through suitable heat exchangers); control equipment, such as ionization chambers, which keeps the system at the desired working level. The permanent operation of the pile is very costly: acquisition of the conversion products, renewal of the charges, neutralization of the radioactivity, subsequent separation of the fission products from the plutonium obtained. All these things must be done by remote control in laboratories. The more separated and concentrated plutonium is obtained, the more U 235 can be dispensed with. It is a great advantage that separation, still difficult and tedious, can largely be done by chemical processes, as most of the substances to be separated have different atomic numbers, hence different chemical characteristics. The laboratories of the separating plants, empty of all humans, are built in canyons, and are controlled by specially protected personnel from a safe distance with the aid of optical apparatus resembling periscopes, and other mechanisms.

Present development—of importance to us—is aiming at making these installations smaller by improving conditions. There are small piles producing a limited amount of energy. In spite of the secrecy over details it can be taken as certain that the exact measurement of many physical data, a more detailed knowledge of the transuraniums, the development of refining and separation methods, the opening up of rich new mineral deposits, and knowledge of the dangers and protective measures have advanced so far that the construction of mobile energy producers on the basis of nuclear fission is already under way, with good prospects of success within the foreseeable future.

OBTAINING ENERGY FROM NUCLEAR FUSION

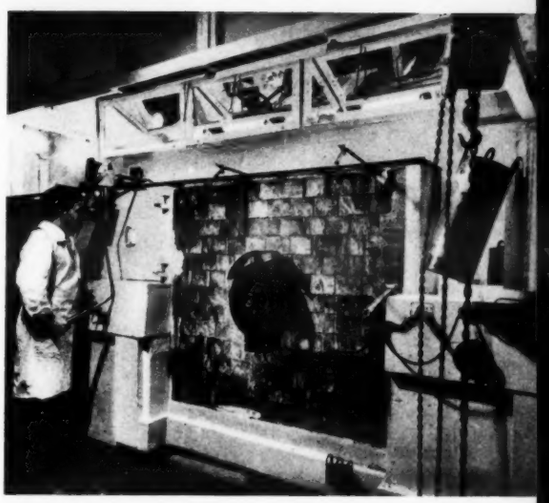
The essential difference in the liberation of energy by fusion as against fission consists in the fact that here two or more nuclei must be *united*. But the nuclei contain protons, so that they repel each other by strong Coulomb forces when they approach one another. Neutrons, which have no charge, are not repelled by nuclei. Therefore the nuclei must be so accelerated, by powerful laboratory equipment such as the cyclotron, that they overcome the Coulomb forces. This can be done, and fusion reactions are therefore known. It is well to start with hydrogen isotopes, with deuterium (deuteron) which contains not only a proton but also a neutron and is consequently written $_1D^2$ or $_1H^2$ and with tritium with two neutrons and formula $_1T^3$ or $_1H^3$. Heavy water (D_2O) and tritium are now available in sufficient quantity. It is conceivable that it will be possible to produce a helium isotope nucleus $_2He^3$ in the laboratory with fast deuterons [7].

The release of the binding energy of the deuteron and tritium (4, 11.4, 17.6 MeV) seems small in comparison with the 200 MeV released by the fission of U 235. If, however, the energy released is compared with the weights, production is much greater. There is, of course, no prospect of arriving at such a process with bundles of fast deuterons produced in the laboratory. The probabilities (nuclear cross sections) of fusion collisions are far too small. At a high energy level on the other hand, such as in the interior of the sun, where the temperature is about 20 million degrees, the thermal speed of the particles is higher. At this temperature it corresponds to an individual energy of not quite 2000 electron volts. Calculations made by Gamov, A. Bethe and others show that in an immense volume, such as the interior of the sun, the nuclear cross sections are sufficient to maintain the internal temperature by (complicated) fusion processes [8].

The fusion reactions, because dependent on temperature, can take place only at similar levels of high energy. Although deuterium and tritium reactions require less high temperatures than the Bethe reaction, they cannot be produced by technical means for prolonged use. Therefore, in the general view of the experts, energy originating from fusion could only be used in the atomic bomb, and even then only as an *additional measure*. In the chain reaction of U 235 or plutonium in an atomic bomb such high temperatures occur in the centre of the reaction that rapid nuclear fusion takes place and increases or even magnifies the explosion. This is therefore a question of the *addition* of deuterium or tritium to the nuclear fission substances for momentary effects—not of the possibility of the long term provision of useful energy.

There are a number of other "exotherm" fusion reactions, *e.g.* with the lithium isotope $_3Li^6$ (with protons and with tritium), with beryllium, boron and so on. The same applies to them all. They can only take place at a high energy level. This path would therefore seem to be closed and there would be no more talk about it were it not for the fact that the official statements by the Argentine atomic expert Professor Ronald Richter had revived the subject again in recent weeks.

No scientific details have yet been made available so that nothing can be checked. This has led to a certain scepticism among experts. Richter spoke, according to press reports, of a huge "sun pile," of "thermal nuclear reactions," without the use of the uranium process or of tritium. The high speeds



The substances emerging from a plutonium production unit are dangerously radioactive and can be further treated only in special laboratories under remote control. The chemist stands behind thick protective walls built up of lead blocks. He looks into the inside of the laboratory through a periscope, and transfers a solution there by means of a syringe. Other parts of the laboratory can be seen through mirrors. The lead-encased end of the connecting tube can be seen in the centre.

required in the reacting partners were said to be obtained in a new way.—All these indications show that it must be a new nuclear reaction at high temperatures. It seems improbable—but there have often been surprises in scientific research. Let us wait and see.

CONCLUSION

At the present time the only feasible methods of obtaining energy for industrial use (leaving aside the Argentine report) are those based on the fission processes, *i.e.* on U 235, thorium and plutonium. If it is a question of producing, without any particular regard for cost, *small sources of energy*, of limited output (so-called breeder piles), it is possible at the present stage of experience to build effective transportable units from highly concentrated fission substances (with moderators, reflectors, controls), for example to propel ships and giant aircraft. These technical problems would appear to be capable of solution within the near future. The products occurring, such as plutonium and radioactive substances, may be lost in the process. Breeder piles of this kind are under construction at Harwell and in the U.S.A.

Large power stations can be built of less pure and concentrated materials. They have good prospects of becoming an economic proposition if the by-products, radioactive substances, chemicals, and the plutonium can be utilized and the danger of the concentration of radioactive substances can be effectively overcome. They must be converted for operation at high temperatures (this is now being done). Considerable difficulties in connection with materials must be overcome, for in addition to the temperature stresses on the structural materials there are the ravages of radioactivity to be dealt with. As one ton of uranium *ore* (of which there is plenty) gives as much energy as 300 tons of good coal, as the *full* fission decay of one ton releases as much energy as the combustion of three million tons of coal, as the earth's coal supplies, according to present-day estimates, will only last for about another 150 years, these difficulties will undoubtedly be overcome.

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[7] The reaction, which has been calculated by Gamov, is written :—

$$_1H^2 + {}_1H^2 \rightarrow {}_2H^3 + {}_0n^1 + 4 \text{ MeV}$$

Considerably more energy is liberated by :—

$$_1H^2 + {}_1H^2 \rightarrow {}_2He^4 + {}_0n^1 + 17.6 \text{ MeV}$$

and $_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + {}_0n^1 + {}_0n^1 + 11.4$ MeV.

[8] "Atomenergie und Atombombe," referred to earlier, describes the most common process in our sun, after A. Bethe.

Atomic Power Plants for Aircraft

First reference to the possibility of using atomic energy for aircraft power plants was made in this journal four years ago[1]. Although since then further millions of dollars have been poured into the laboratories of the American NEPA project (Nuclear Energy for Propulsion of Aircraft), research is still in its infancy. So far only preliminary investigations have been made, most of them by the NEPA Division of Fairchild Engine and Airplane Corp. and nine other aircraft and engine firms. The National Advisory Committee for Aeronautics (NACA) and a number of Universities have also worked in this direction. The NEPA project was officially concluded in April 1951. A joint statement issued at the time by the USAF and the U.S. Atomic Energy Commission (AEC) disclosed that "... the first phase of a study leading to the construction of an aircraft powered by an atomic engine is now complete."

And the second phase? Exactly 24 hours after the above statement, it was announced that development of a nuclear power plant for aircraft will "shortly" be begun at the Gas Turbine Division of General Electric, at Lockland (Ohio). And as it is already clear that only a giant aircraft could carry such an atomic engine, Consolidated Vultee, makers of the 350,000 lb. B-36 super-bomber, have recently been commissioned to design a suitable airframe. —Finally NACA's annual report for 1950 shows that the sub-committee for heat-resistant materials has been carrying out extensive research into one of the main problems of atomic power plants, namely protection against radiation (particularly from gamma rays)[2].

ONLY THE HEAT ENERGY CAN BE USED

So much for the official reports. They are meagre enough and give no clue whatsoever to the two basic questions, namely:—

1) Nature of atomic reactor used to produce the heat;
2) Nature of the thermal power plant producing the thrust.

However, it still appears to hold good that of all the types of energy released during the nuclear reaction (through the disappearance of mass) only *heat* can at present be used technically. The conversion of the electro-magnetic gamma rays (which form the highly undesirable bulk of the energy released) into low frequency electric energy will long remain a dream of the future[3].

The utilization of heat energy is always dependent on the existence of a *difference in temperature:* the highest temperature occurs in the atomic reactor. The lowest temperature is reached by the working fluid of the thermal power plant, either when emerging into the outside atmosphere (e.g. in the jet turbine or the ram jet) or when passing through a condenser (e.g. in the case of a mercury-vapour turbine driving a propeller). This therefore imposes relatively narrow technical limitations. On the one hand the temperature in the reactor must not be so high that its structural elements melt or that the fuel of the thermal power plant becomes contaminated with radioactive fission products as a result of increased diffusion through the heat transfer walls[4].

On the other hand the thermal power plant requires a high minimum temperature in order to provide an adequate power output. The lower the working temperatures, the bigger and heavier must be the reactor and its radiation shield. In other words the problem is to find, between the fixed, several-storied, water-cooled atomic pile which works at temperatures of less than 100°C and the relatively minute atom bomb which releases temperatures of several million degrees, a middle course which is technically suitable for aircraft engines.

STRUCTURAL PRINCIPLES FOR AIRCRAFT REACTORS

In his famous lecture to the Society of Automotive Engineers (Detroit, February 1948)[5], for which he received the Manly Memorial Medal in October 1948, *Andrew Kalitinsky* discussed certain basic principles for aircraft reactors. He explained that:—

1) To reduce the "*critical mass*" required for the chain reaction[6], an atomic power plant will (a) be run either on the *uranium isotope U 235* or on the artificial element *plutonium* (Pu 239); (b) contain *moderators* (beryllium, graphite, heavy water, etc.) to slow down the neutrons; (c) have to be provided with *reflectors* (similar substances to the moderators) to reflect the neutrons back into the reactors; (d) be made of materials which do *not* absorb neutrons (high degree of purity).
2) The atomic reactor must be designed for "correct" *working temperatures* and have suitable heat transfer areas. (No figures were given, but it seems that the immediate plan is to enclose the blocks of uranium—or plutonium—in aluminium casings to protect the working fluid of the power plant from contamination by radioactive fission products. This would limit the working temperature of the reactor to considerably less than 660°C, the melting point of aluminium.
3) The whole chain reaction (above all the working temperature) must be capable of *reliable control.* —Such control is exercised by inserting neutron-absorbing *cadmium rods* (or boron rods). When the whole length of these rods is inserted into the pile the chain reaction is broken completely, whereas as they are withdrawn it takes place with an increasingly great "reproduction factor." This is therefore a question of a "higher order" control, since it can have no direct influence on the power output of the pile but only, owing to the nature of the chain reaction, on the reproduction rate of the neutrons. Hence, constant fine adjustment of the cadmium rods is essential. It is also advisable to arrange them in several systems.

[1] Cf. "Interavia, Review of World Aviation," Vol. II, No. 4 (April, 1947), p. 55, and Vol. II, No. 9 (Sept. 1948), pp. 507-508.

[2] NACA: Technical Note 2026, also 1919, 1952 and 2108.

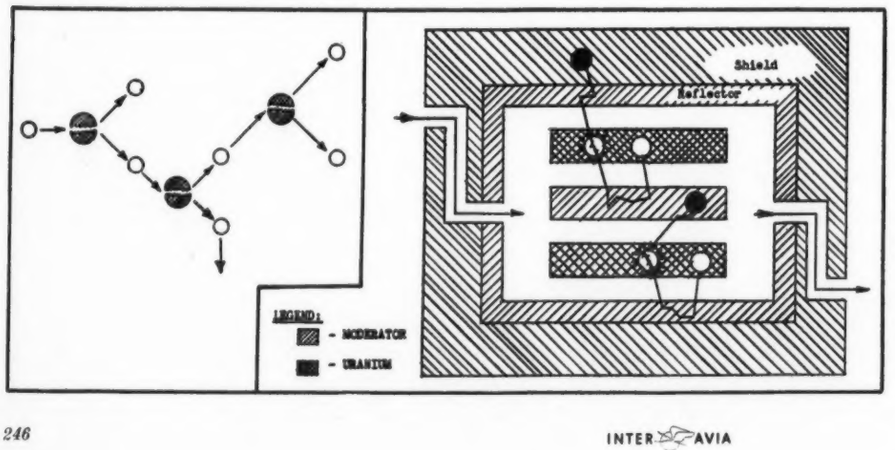
[3] When 1 kg of Uranium U 235 splits up into barium, krypton and other elements (through nuclear fission) about 1 gram of mass disappears. According to Einstein's theory of relativity therefore an energy of $m \cdot C^2 = 1 \cdot 3^2 \cdot 10^{20}$ (g . cm²/sec²) = $9 \cdot 10^{20}$ Erg = $9 \cdot 2 \cdot 10^{12}$ mkg = $25 \cdot 10^6$ kWh = 22×10^9 Kcal is released, though only to a very small extent in heat, with the remainder in gamma rays and kinetic energy of matter particles.

[4] This would mean that the power plant would also become more or less radioactive, i.e. could not be maintained or inspected from close quarters. Every effort is doubtless made to confine the centres of radiation and as far as possible restrict them to the reactor and its attendant heat exchangers.

[5] "Atomic Power and Aircraft Propulsion," Cf. SAE Quarterly Transactions, Vol. 3, No. 1, January 1949, also, in extract form, The Aeroplane, Feb. 9th 1951, pp. 172-177.

[6] The "critical mass" must be of such a size that sufficient neutrons can always collide with uranium nuclei so as to continue the chain reaction. Otherwise the neutrons would escape completely or be absorbed by the radiation shield and the chain reaction would be broken. Even uranium and plutonium, the heaviest metals, resemble a very loose network in their basic structure. If, for example, the nuclei were the size of pinheads they would be 250 ft. apart. The lower the speed of the neutrons (owing to the presence of moderators) the greater are their chances of colliding with a nucleus.

Structural diagram of an aircraft atomic reactor according to A. Kalitinsky. Left: the chain reaction in the fission material (uranium 235); right: how the reactor works. The fast neutrons emitted by the fission material are slowed down by the moderator (e.g. graphite), and turned back by the reflector, and cause new fissions—unless they are captured by neutron absorbers (e.g. cadmium; *not* shown here) or impurities in the moderator (black spot) or in the neutron shield (e.g. cadmium; black spot). Arrows show the direction of flow of the working fluid in the thermal power plant (or the heat exchanger).



4) The atomic pile must be surrounded by a thick shield, which on the one hand absorbs or slows down the *neutrons* (by collisions with nuclei in the shield) which escape from the reactor despite all the measures taken to prevent them[7], and on the other hand absorbs the electromagnetic *gamma rays* (through the electrons in the shield) or converts them into softer gamma and X-rays. (The more efficiently the reflector works the fewer neutrons the shield will have to deal with, but a very thick, heavy lead jacket will still be required for the gamma rays.)
5) Since the intensity of radiation decreases as the square of the distance, the atomic reactor in an aircraft must be installed as *far* as possible away from the crew. Its shield must be particularly thick in the direction of the crew and the rest of the airframe, though it can be thinner where the power plant gives on to the open air.

Nevertheless the most difficult problem connected with the aircraft atomic power plant is still undoubtedly that of the permissible working temperature, i.e. the characteristics of its materials (structural material, canning). Temperatures of under 600°C are perhaps adequate to operate a steam turbine or a mercury-vapour turbine (boiling point of mercury at normal pressure 357°C); for a jet turbine or a ramjet, however, pile temperatures of over 1000°C will probably be required. Consequently pure aluminium, which is otherwise highly suitable as a canning material for uranium blocks and structural material for heat exchangers, must be replaced by other metals with higher melting points (e.g. beryllium, titanium, molybdenum, tantalum, tungsten, zirconium) or by ceramic substances. To reduce the radioactive contamination of the propulsive unit proper several heat exchangers and additional working fluid circuits will probably be provided, so that still greater temperature differences will be required.

THERMAL POWER PLANTS FOR PROPULSIVE POWER

The following types of power plant can be used to convert the heat energy into propulsive thrust (again according to Kalitinsky).

1) Steam (or mercury vapour) turbines with subsonic or supersonic propellers, condenser and pump;
2) Jet turbines or propeller turbines;
3) Ramjets (for supersonic flight);
4) Hydrogen rockets (primarily for flight outside the earth's atmosphere).

The most easily realisable of these at the present day would seem to be a power plant falling within the first group, both from the point of view of working temperatures and because supersonic propellers for flight on both sides of the sonic barrier are already under development and will be ready for practical use within the foreseeable future, so that a power plant of this type would also be suitable for high speed flight conditions. Mercury is obviously a more suitable working fluid than water which partially breaks up under the influence of the neutron bombardment and must constantly be freed of hydrogen and oxygen.

In the jet turbine the reactor—or the heat exchanger attached to it—replaces the combustion chambers and heats the air supplied from the compressor to a temperature of 750° to 900°C. Thus higher working temperatures are needed here than in the steam turbine. Whether the propulsive thrust is produced by a jet nozzle or by a propeller is of secondary importance. In the latter case it would also be possible to use helium or a carbon gas as working fluid instead of air, passing it round a closed circuit via a cooler.

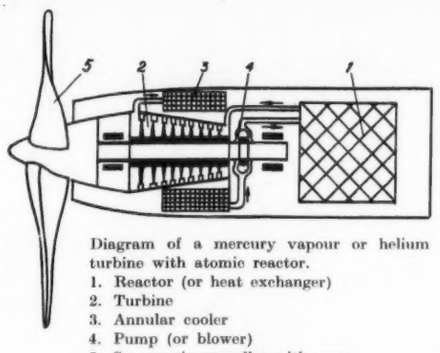


Diagram of a mercury vapour or helium turbine with atomic reactor.
1. Reactor (or heat exchanger)
2. Turbine
3. Annular cooler
4. Pump (or blower)
5. Supersonic propeller with gear

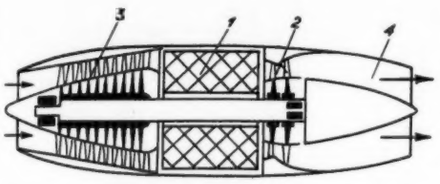


Diagram of a jet turbine engine with atomic reactor.
1. Reactor (or heat exchanger)
2. Turbine (two-stage)
3. Compressor
4. Jet nozzle

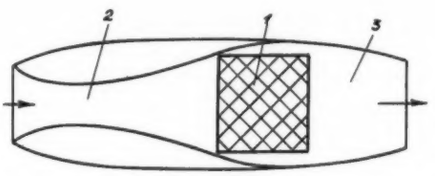


Diagram of a ramjet with atomic reactor.
1. Reactor (or heat exchanger)
2. Intake diffusor
3. Jet nozzle

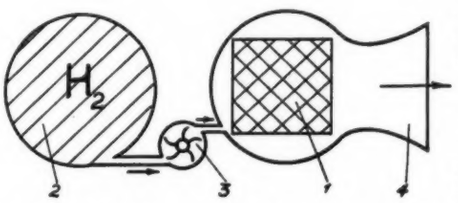


Diagram of a hydrogen rocket with atomic reactor.
1. Reactor
2. Liquid hydrogen container
3. Pump
4. Reactor nozzle

Still higher working temperatures (over 1000°C) would be required for a ramjet. In this case the reactor (or its heat exchanger) opposes much greater resistance to the internal flow than the present-day direct fuel injection into the pipe. Thus the ramjet power plant would be suitable only for very high supersonic speeds and would have to be replaced by auxiliary power plants (jet turbines or rockets) for subsonic flight. Although an atomic ramjet appears to be remarkably simple at first glance—no moving parts, very short passages for the working fluid, no special maintenance—there are tremendous difficulties to be solved in regular operation and it would seem to be far more suitable for guided missiles than for aircraft.

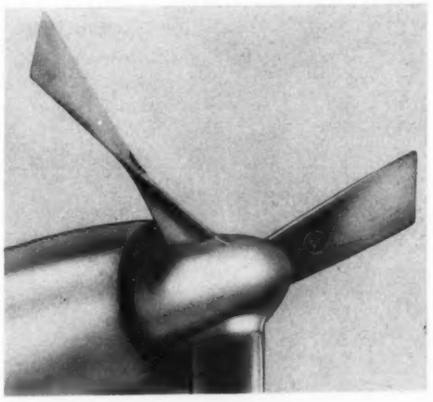
Rockets driven by atomic power will be used in aviation only as auxiliaries (e.g. as take-off rockets). Instead—though in the distant future—they probably will be used for space travel. The high energy concentration of the atomic fuel represents only one side of the rocket's power. In addition it consumes vast quantities of mass which it pushes rearwards by means of thermal energy. Whereas all the types of power plant so far described use atmospheric air as "recoil mass," taking it from the surrounding atmosphere, the rocket has to carry all its mass with it[8]. In cases where weight (specific impulse) is of primary importance liquid hydrogen will be used as mass carrier. When it is desired to carry the maximum possible recoil mass in the available tanks a heavier propellant (e.g. mercury) will be chosen. A space rocket, which need scarcely be concerned about radioactive contamination of its propellant, would of course run at the highest temperatures which its structural materials could withstand, i.e. several thousand degrees, and at correspondingly high exit velocities (7000 to 10,000 m/sec for hydrogen).

*

But let us return to *terra firma*. It will most probably be years before an atomic aircraft engine and the giant aircraft to carry it can be produced. Even under the most favourable conditions—minimum critical mass of atomic fuel and size of reactor, highest working temperatures, thinnest possible radiation shield—a power plant of this kind must be expected to weigh at least 100 tons, i.e. roughly the weight of power plant plus fuel in the B-36 super-bomber. On the other hand an atomic-powered aircraft could remain in the air almost indefinitely, whereas the B-36 has to land and refuel after covering 10,000 miles.

There is little doubt that atomic power will be easier to apply to ships and submarines. Here, too, unlimited range is a particularly valuable quality. Submarines have already reached the 10,000 ton level, so that even the extra weight required for radiation shielding (lead sheets and concrete) is no real problem. The U.S. Atomic Energy Commission therefore expects that an atomic power plant for ships will be produced before an atomic aircraft engine.

A Curtiss Wright supersonic propeller "Turbosonic" model. Theoretical maximum speed 1000 m.p.h.



[7] Protection against the two other particle radiations, alpha particles (helium nuclei) and beta particles (electrons) entails no particular difficulty. Neutrons can best be held off by cadmium and concrete—but the latter is not the most suitable material for aircraft construction.

[8] Dr. Hsue-Shen-Tsien, the American scientist of Chinese descent, has calculated that for a terminal velocity of 8,145 m/sec a liquid hydrogen rocket powered by U 235 (atomic fuel) and U 238 (moderator) in the ratio of 1:1 would have a take-off weight of 750 tonnes with a power plant diameter of 3.75 m and a thrust of 1250 tonnes over 358 sec. The take-off weight would include 601 tonnes of hydrogen and 16 tonnes of Uranium (cf. "Science et Vie," 1951, "L'Age atomique," p. 137).

A-Bomb Transports

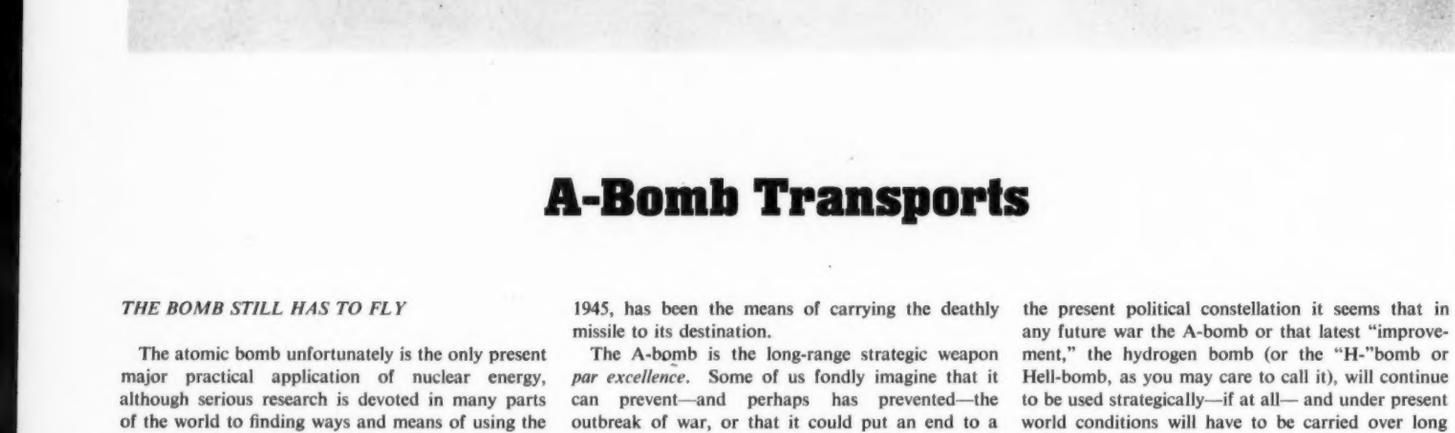
THE BOMB STILL HAS TO FLY

The atomic bomb unfortunately is the only present major practical application of nuclear energy, although serious research is devoted in many parts of the world to finding ways and means of using the tremendous power released by atomic fission and synthesis for peaceful ends. While a bomb could be set off anywhere at any time, an important subsidiary problem which has preoccupied strategic planners since long before the first experimental explosion in the New Mexico desert on July 16th, 1945, has been the means of carrying the deathly missile to its destination.

The A-bomb is the long-range strategic weapon *par excellence*. Some of us fondly imagine that it can prevent—and perhaps has prevented—the outbreak of war, or that it could put an end to a war very quickly. Practical experience in World War II has shown that it can profoundly affect the course of war and that it can persuade an exhausted enemy to lay down his arms. It has never been used otherwise than strategically; its tactical application still is a subject of controversy. And under the present political constellation it seems that in any future war the A-bomb or that latest "improvement," the hydrogen bomb (or the "H-"bomb or Hell-bomb, as you may care to call it), will continue to be used strategically—if at all— and under present world conditions will have to be carried over long distances.

Had the A-bomb been ready before the end of the war in Europe, a mere fraction of the huge Allied strategic bomber forces would have sufficed to inflict more damage on Germany in one raid than the Allies did in hundreds. Since that time the world has been

The "A-bomber" of today : the huge size of the Consolidated Vultee B-36 ten-engined intercontinental bomber dwarfs the Gloster "Meteor" twin-engined jet fighter parked next to it. Six of the big aircraft recently made a non-stop practice flight from Fort Worth, Texas, to Lakenheath RAF Station, England.



split into two much more clearly defined camps, the nerve centres of which are very widely separated. Though the wartime A-bombs were ultimately flown to Hiroshima and Nagasaki over relatively short ranges, it had taken the U.S. Army, Navy and Air Force three-and-a-half years to move up within striking range.

Obviously, it is not possible to foretell how another major war may happen. There is the likelihood that it will open by a sneak A-bomb attack designed to cripple the enemy, or at least to destroy a maximum of his war potential and civilian morale, with one blow. Or it might take the form of retaliatory attacks, perhaps after an ultimatum, by nation A because nation B has started some kind of aggression against A's ally, nation C. Again, it may start "nice" enough with conventional methods of mass murder and degenerate into a "nasty" atomic war only in the course of time. But considering that known major potential users and manufacturers of atomic bombs number precisely two, it seems clear that in World War III the bombs would have to travel a longer way to their targets than ever before.

In the minds of some people there still is doubt as to how this transport mission will be accomplished. There are those who take a page out of the blackest book of treachery and forecast that A-bombs could be smuggled into "enemy" ports in times of peace and set off on "D" day. Effective precautions are being perfected against this possibility, notably by the immediate discovery of any radioactive material merchant ships might have aboard. Others claim that World War III will be a "push-button" war with accurately guided missiles carrying atomic war heads over thousands of miles. Responsible engineers and military men discount this possibility for the present. Later perhaps, say in twenty, fifty years' time.

Thus, the carriage of the bomb to its target continues to be the lot of the long-range bomber aircraft. Russians and Americans are expending vast amounts of energy, effort and money on the development of aircraft capable of ensuring the delivery of the bomb to the right place at the right time. Getting there "fustest with the mostest" will count more than ever in the next war. While it is admitted that not much is known about Russia's success or failure in building large, long-ranging bombers, the odds are that the United States is leading the field by several lengths. The U.S. Air Force dropped the A-bomb on Hiroshima and Nagasaki from Boeing B-29 "Superfortress" four-engined bombers six years ago. The chosen "A-bomber" of the post-war USAF is not the improved B-50 "Superfortress" but the Consolidated B-36 ten-engined giant bomber, dozens of which are in squadron service. The Russians, on the other hand, apparently are concentrating their long-range bomber production efforts on the Tupolev Tu-4, a close copy of the American B-29 "Superfortress," four of which force-landed in Soviet territory in the latter stages of the war and saved the Russians the trouble of designing their own prototypes.

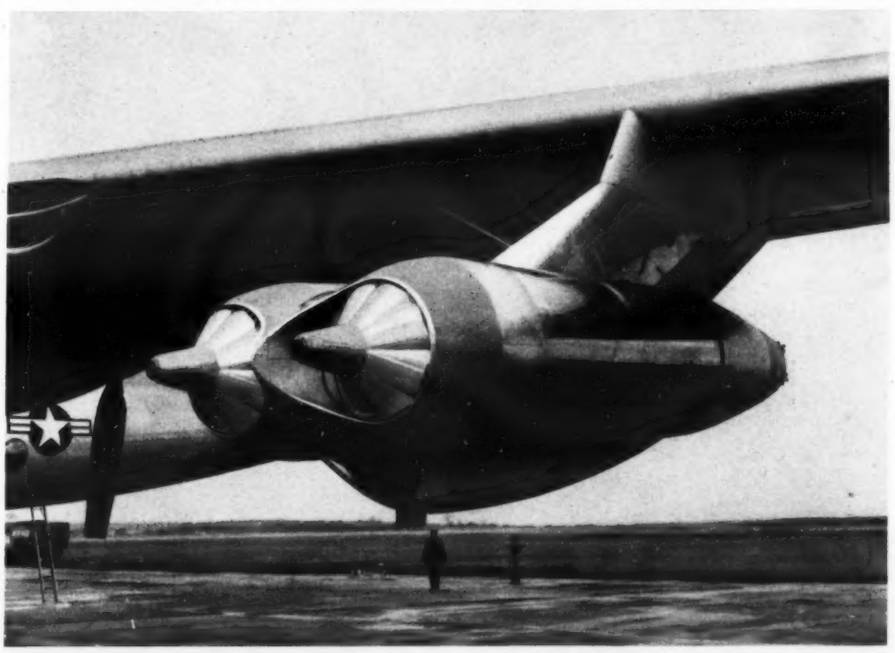
USAF heavy bomber equipment plans call for aircraft capable of intercontinental strategic bombing, *i.e.*, of bombing the "heartland" of any potential enemy and returning to bases in the interior of the USA without refuelling. Contenders for the strategic bombing rôle must meet or exceed a set of minimum performance requirements providing a theoretical guarantee that they can complete their assignments. Roughly these requirements are as follows:

Range: 10,000 miles, or a combat radius of 5,000 miles, which is regarded as sufficient to reach any target of strategic importance and return to the U.S. mainland without refuelling.

Bomb load: 10,000 lbs., which is not very great for "normal" HE-bombs (single 40,000-lb. bombs

The top of the B-36's tail is 47 feet above the ground. Anita, five-year-old daughter of USAF Captain Alexander Rodriguez, seems duly impressed at Carswell Air Force Base, Fort Worth, Texas.

Close-up of the port dual pod of a B-36, containing two General Electric J-47 jets of 5,000 lbs. static thrust each.



were built during World War II!) but should suffice to carry even the biggest A-bombs.

Speed: The higher the speed of a bomber at very great altitude, the more difficult will it be for interceptors to reach the raider. Top speed of present and projected strategic bombers is to be between 450 and 600 m.p.h.

Combat Altitude: Above 50,000 ft., where the manœuvrability of heavily wing-loaded fighters is impaired.

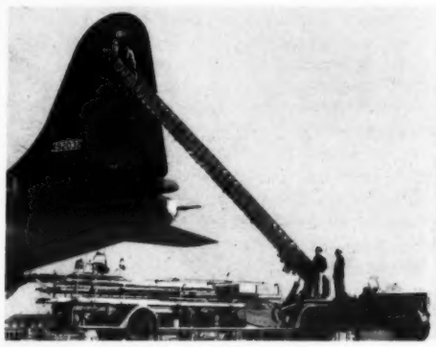
The American strategic bomber programme can roughly be divided into three phases: *today*, *tomorrow* and "*sometime*." The inference is that push-button warfare still is out of the question and the aircraft will remain the A-bomb vehicle for many years.

Today

Today's standard strategic long-range bomber of the USAF is the ten-engined *Consolidated Vultee B-36*, of which about 250 have been ordered (and about 100 delivered). The latest version, the B-36D, has six Pratt & Whitney "Wasp Major" engines of 3,500 h.p. for cruising, plus four General Electric J-47 jets of 5,000 h.p. each for extra speed in combat. Cruising speed is about 350 m.p.h., emergency combat speed just under 450 m.p.h. Wing span is 230 ft. length 162 ft., gross weight about 320,000 lbs. range 10,000 miles, ceiling over 50,000 feet, defensive armament sixteen 20-mm cannon. The B-36 is the largest, most powerful, technically the most complex and the most expensive bomber existing in the world today. Without accessories a production aircraft costs about $3,500,000. Its fuel supply (for the piston engines alone) exceeds 21,000 U.S. gallons. Crew quarters are fully pressurized and incorporate an 80-foot tunnel, complete with rails and trolley, along which crew members travel from the main cabin to the rear compartment. The big bomber carries facilities to prepare hot food, and package meals include steaks, chops and all the trimmings. At 50,000 feet, in extreme sub-zero temperatures, the men will be able to enjoy a Swiss steak, mashed potatoes, diced carrots, bread, butter, coffee...

B-36 bases have been established at various points in the USA, notably at Fort Worth, Tex.; Tampa, Fla., and Atlanta, Georgia. Bases large enough to accommodate the big bombers are available in Alaska, and at least one is reportedly being prepared in England. Night after night B-36s roar down the runways of their fields, taking off on practice missions over 6,000 to 10,000 miles, simulating A-bomb raids on American cities while their inhabitants are asleep. Strategic Air Command under General Curtis E. Le May means to be prepared for any eventuality.

Crew of the B-36 normally numbers 15, including four-man relief crew, but 13 or 14 men only are carried on shorter flights. Crews are never changed and form integrated combat teams. Their social as well as military life is keyed to develop teamwork, cooperation and faith in each other's ability. Never more than one hour's driving distance from their aircraft, the crews are permanently "on call" for any emergency. Crews normally comprise 2 pilots (including aircraft commander), 3 flight engineers, 2 radio operators, 3 observers, 4 gunners, 1 electrician-gunner. Crew above has only two flight engineers and one radio operator.



The ladder of a fire-engine is needed to inspect the three-storey high vertical tail of the B-36.

Flying on a long training mission, B-36 crews get a chance to rest in aft compartment. Radio Operator Sgt. William C. Porter reminds Flight Engineer 1st Lt. Earl C. Hayden that his "sack time" is over.

TOMORROW

For years the procurement chiefs of the USAF have given consideration to the problem of replacing the piston-engined B-36 series—which, after all, was first put into production in 1946—with more modern, faster aircraft. Thanks to this long-range planning, the immediate successor to the B-36D already has passed beyond the project stage, although several years will no doubt pass before it enters squadron service. Other replacements are coming along at the same time.

Most advanced is the *Boeing B-52*, which originally was intended to take eight propeller turbines delivering 5,500 shaft-horsepower each (Wright T-35 "Typhoons") but subsequently was redesigned for eight turbojets, probably Pratt & Whitney J-57s of nearly 10,000 lbs. static thrust each. The eight engines will give the type the fantastic combined power of about 80,000 lbs. of static thrust...

The B-52 has had a somewhat checkered career. Boeing Airplane Co., famous bomber specialists and designers of the well-known B-17 "Flying Fortress" and B-29 "Superfortress" wartime heavy bombers, as well as the B-50 "Superfortress" and B-47 "Stratojet" post-war types, in 1947 began development work on this aircraft with the special aim of reconciling the two apparent irreconcilables: very high speed and very long range. USAF ordered two prototypes and envisaged a production contract later on.

Early in 1950 it was announced that production plans had been dropped, that the B-36 would remain the backbone of Strategic Air Command until the

advent of push-button guided-missile warfare, and that only the two B-52 prototypes would be completed. In the meantime, the picture has changed again. The aircraft *will* go into production after all, possibly because sufficiently powerful engines have now become available. The first prototype is expected to make its maiden flight later this year, a production contract has been awarded, and in due course the machine will take its place in the squadrons of S.A.C.—next to the B-36D and newer contenders.

Its gross weight will be about 350,000 lbs., range 11,000 miles at a cruising speed of 400 m.p.h. (on four engines only), top speed about 600 m.p.h. with all eight jets in operation. Wings and tail surfaces are swept back 35 degrees. Crew will be nine men, including relief personnel for long missions. Each of the two B-52 prototypes will cost about $8,000,000, but production models evidently will be much cheaper.

Following close behind the B-52 is its old rival in a new guise, the *Consolidated-Vultee B-36F*. At the time it awarded a B-52 production contract to Boeing Airplane, USAF also ordered the prototype of the B-36F from Convair. This aircraft will be powered with eight General Electric J-47 jet engines of about 5200 lbs. each arranged in four underslung dual pods and will feature the now customary 35-degree wing sweep angle. Maximum speed is expected to be in the region of 500 m.p.h. at 50,000 ft.

An alternative version of the B-36F calls for installation of six propeller turbines in conventional wing nacelles with residual-thrust jet pipes projecting beyond the wing trailing edge. This aircraft, too, will have a 35-degree swept-back wing. Top speed would be about the same as that of the pure jet model, range somewhat longer.

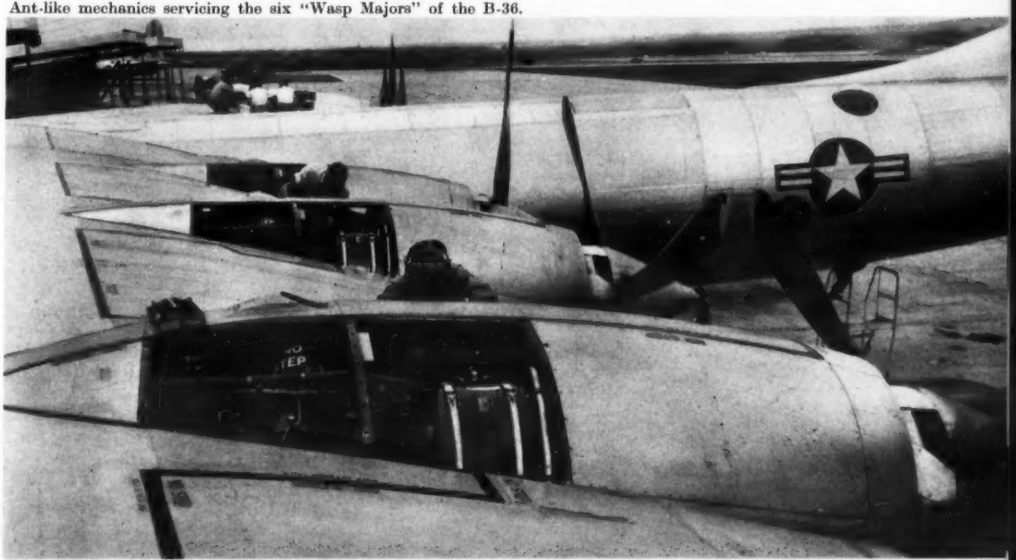
A dark horse in the contest for the part of tomorrow's strategic bomber rôle is a design elaborated by the Douglas Aircraft Company, the *Douglas 1211-J*. "Aviation Week," the usually well-informed U.S. aviation news magazine, reported at the end of January that USAF design specialists were studying the project—submitted almost a year previously—with renewed interest. While Douglas Aircraft spokesmen refused to confirm the existence of the project, the source describes the aircraft as a four-engined propeller-turbine aircraft with a gross take-off weight of 320,000, a normal absolute range of about 12,000 miles, a combat altitude of over 55,000 feet and a speed considerably in excess of 500 m.p.h. The Douglas bomber apparently features sharply swept-back wings of an aspect ratio of 12 and a target wing-loading of 50 lbs./sq.ft., wing-tip tanks, slender fuselage with a pressurized compartment for a nine-man crew, radar equipment, defensive armament of 20-mm cannon, and provision for firing air-to-air rockets. Another feature would be a novel jettisonable take-off gear weighing 2,000 lbs. (not included in gross weight). Fuel load would be 170,400 lbs., of which 50,000 lbs. would be carried by wing tip tanks. An escape hatch for the crew would be provided in the underside of the fuselage between the nose-wheel doors and the forward bomb bay.

The disclosure of the design by the American weekly caused a flurry in USAF procurement circles. Subsequently it was discovered that the writer, wandering around in the huge Pentagon Building in Washington, headquarters of the U.S. armed forces, had gathered his dope from a poster which was displayed for all to see...

It is obvious that the "second generation" of strategic atom-bomb carriers, destined to take over from the present B-36D some time after 1955, will not suffer from a lack of variety. Four models are known to be under study, and it may be taken for granted that other American designers, notably Lockheed, also have their ideas on the subject.

Engine maintenance on the B-36 : One of the huge Pratt & Whitney "Wasp Major" 28-cylinder four-row radials of 3,500 h.p. is being changed.

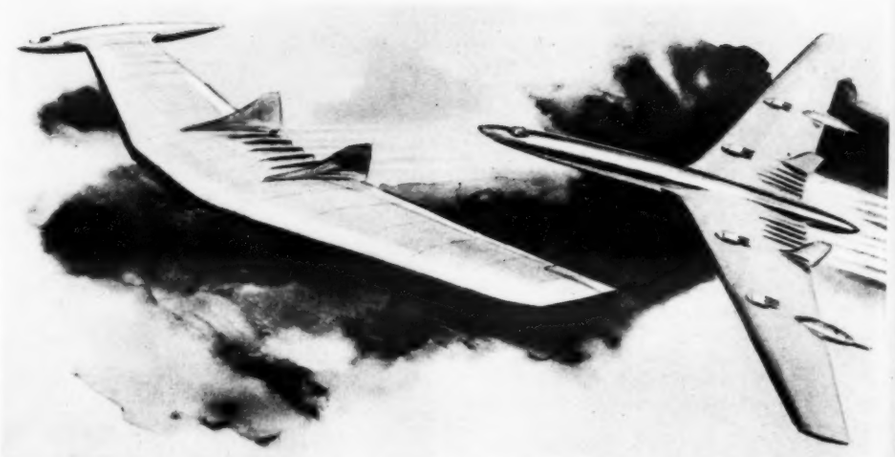
Ant-like mechanics servicing the six "Wasp Majors" of the B-36.



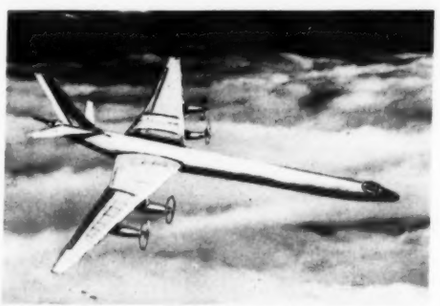
"Sometime..."

How long the Boeing B-52s, the Convair B-36Fs or the Douglas super-bombers will remain in service with the USAF is an open question. But it is reasonable to assume, in view of the long development periods required for aircraft of this category and the constantly recurring possibilities of improvement as time goes on, that their later versions will not be ready for the scrap-heap before 1965 or even 1970. Since it would be rash to hope that by then the world will have turned itself into one great happy family, the brains planning the future procurement of the air forces are already speculating on the kind of equipment that will be available when the time for replacement approaches.

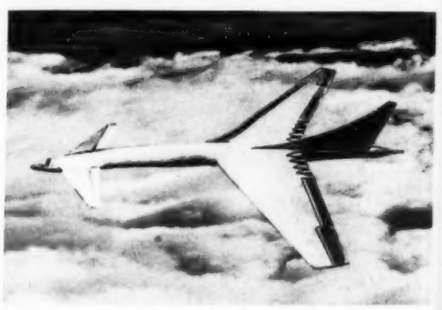
Experts seem to be unanimous that the "third generation" of A-bomb carriers will represent a spectacular step forward in the design of aircraft, inasmuch as these aircraft will be driven *by atomic power plants*. Atomic aircraft engines are theoretically feasible, as explained elsewhere in this issue. Work on the practical application of nuclear energy to aircraft propulsion is being pressed forward with more zest than ever before, as is indicated by the completion at the end of April of the famous U.S. NEPA project (NEPA stood for Nuclear Energy for the Propulsion of Aircraft), the prime contractor for which was the Fairchild Engine and Airplane Corporation, assisted by ten U.S. aviation and engineering companies.



"Atom-powered" bombers : in model at *left*, crew would ride in wing-tip compartment as far as possible from power plant's radiation. Atomic engine is in centre of wing. In aircraft at right, crew is in nose of long fuselage, far from engine. Remote-controlled guns are mounted on wing.

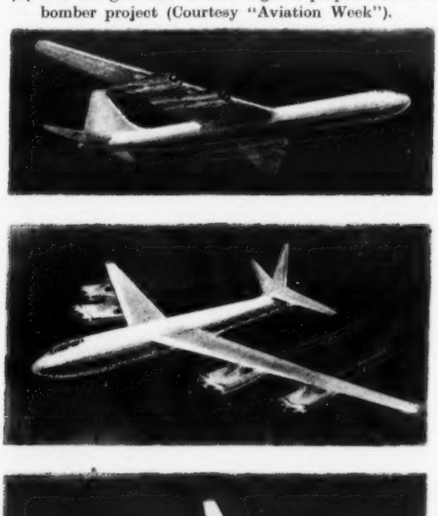


One atom-powered bomber project provides for aircraft to be driven by four propellers which in turn are driven by atomic power plant.



Canard-type configuration is adopted in this atom-powered bomber conception, no doubt to make possible very long fuselage for added crew protection.

Tomorrow's Atom-bombers :
(a) The Boeing B-52 eight-jet bomber,
(b) The Consolidated-Vultee B-36F, with eight jets in pods and swept wing,
(c) The B-36F in its propeller-turbine version,
(d) The Douglas 1211-J four-engined propeller-turbine bomber project (Courtesy "Aviation Week").



General Hoyt S. Vandenberg, USAF Chief of Staff, said recently that "atomic flight" was closer than most people realized. This is borne out in a statement issued by the General Electric Co., in February to the effect that "contractual negotiations are under way between the USAF and General Electric for development of a nuclear power plant for aircraft... This activity will be carried on by the Aircraft Gas Turbine Division at Lockland, Ohio." At the same time it was learned that Consolidated Vultee Aircraft Corp., builders of the B-36, would undertake the development of an aircraft which would be powered by the "atomic engine."

These announcements have fired the imagination of the man in the street. One "popular scientist" proclaimed that an aircraft could now be built which might "fly eighty times around the world on one pound of fuel." He specified neither the type of aircraft nor the fuel. On the other hand, Dr. Miles Leverett, who had directed research under the NEPA project and therefore is familiar with the difficulties involved, limited himself to stating that "the indications were good" that the remainder of the knottiest problems, such as the weight of the aircraft and shielding against atomic radiation, may be solved in the foreseeable future.

What will these atom-powered aircraft look like? Dr. Leverett refused to say. He merely stated that "atomic aircraft" would have a heat engine converting the heat from the reactor power plant into thrust. Details of the engine could not be disclosed "for reasons of national security."

One of the principal problems no doubt has been the fact that owing to the heavy shielding required to stop deadly radiation, atomic engines tend to become huge, multi-ton affairs. This radiation indicates one likely course in the design of the aircraft—namely, to house the crew as far away from the engine as possible. Dr. Leverett had said in an interview that "no plane is going to be built which would provide an extraordinary danger to the crew. If everything goes well in the power plant, there will be no danger to the crew beyond the normal dangers of flying."

U.S. West Coast aviation circles are speculating on the shape of the aircraft which Consolidated Vultee is to design, and they have come up with some weird-looking conceptions *. One of these provides for a flying wing with the "hot" atomic engine in the centre and crew compartments at the wing tips. The crew would be far enough from the "furnace" to make a lighter shield practicable, but on the ground the engine would have to be housed in a heavy envelope of concrete. In a similar design the atomic engine would be detachable for storage in a ray-proof chamber.

All these "conceptions," which are claimed to be based on "reports gleaned from interviews with atomic scientists working on the designs of *atom-powered aircraft*," provide for aircraft of an all-up weight of between 300,000 and 500,000 lbs. (the heaviest B-36 weighs about 320,000 lbs.), a large portion of which would be accounted for by anti-radiation shielding. On the other hand, range would be practically unlimited.

The first atom-powered aircraft may have nothing in common with these fanciful drawings. But where there is smoke there always is a little bit of fire, and by 1970 we may see queer-shaped atom-powered atom-bomb carriers hurtling through the skies—still on training flights, we hope.

* Most fertile mind seems to be that of Chris Clausen, who first published these drawings in the "Los Angeles Examiner."

No Escape?

Atom Bomb Protection, 1945 and 1951

Danger! Radioactivity! British civil defence exercise with instruments for radiation measurement.

The Absolute Weapon no longer Absolute?

On 15th November 1945, three months after the two atom bombs had been dropped on Hiroshima and Nagasaki, Truman, Attlee and Mackenzie King, the Canadian Prime Minister, announced (in a joint call for international agreement on atomic control):

> "We recognize that the application of recent scientific discoveries to the methods and practice of war has placed at the disposal of mankind means of destruction hitherto unknown, against which there can be no adequate military defence..."

These three Anglo-Saxon statesmen were by no means alone in their view. They were merely repeating what the leading nuclear scientists of both old and new world had already unanimously agreed on and what no thinking person dared disbelieve. The title, "*The Absolute Weapon*," [1] of a booklet published by Bernard Brodie on behalf of the Yale Institute of International Studies and written for the benefit of the general public, expressed the common view of the effect of the atom bomb. The whole world agreed that it was idle to think of passive defence measures against atom bombs. The only solution seemed to be to strengthen enormously one's own offensive power—so as to frighten off a potential enemy—or to come to an international agreement to control atomic energy.

Two or three years passed during which these two possible solutions were discussed in all their variants by authoritative and less authoritative persons. Governments kept silent. They bought up pitchblende, built research laboratories and—those that were able to—produced atomic bombs.

On 23rd September, 1949, a little earlier perhaps than had been generally expected, it was learned that the East too had not been idle and had learned how to use the new source of energy. And then suddenly official circles again began, towards the middle of 1950, to add their word to the general discussion on the effect of the atom bomb, this time on the subject of possible protective measures. It was not surprising that the U.S.A. should be the first, since it was here that research had made the most progress. With the assistance of the U.S. Department of Defense and the U.S. Atomic Energy Commission the Los Alamos Scientific Laboratory published a 456-page book on the effects of the atom bomb [2]. A foreword by the Civil Defense Office recommends all leading personnel engaged in civil defence planning activities to read the book, and the last chapter concludes: —

> "It will be evident from the material presented in this chapter that adequate protection against the effects of an atomic bomb attack will require very comprehensive and detailed planning. Such planning will be necessary to avoid panic, for mass hysteria could convert a minor incident into a major disaster."

In the same month the Civil Defence Department of the British Home Office issued a 60-page Manual of Basic Training for the Civil Defence Corps [3], which in essentials is a shorter version of the American publication. A foreword by Attlee points out that, attempts at reaching international agreement on the control of atomic energy having so far failed, everything possible must be done to reduce casualties from atomic bomb raids to the minimum.

A slightly abridged translation of this British pamphlet has been published for use in Switzerland and contains similar recommendations by the head of the Swiss Federal Military Department and the head of the Civil Defence Section [4]. The same pamphlet (without official introduction) is also on sale in Germany under the lurid title, "Atombomben auf Deutschland" (Atom Bombs on Germany). Similar texts in French, Swedish, Italian and other European languages have also been available since the end of 1950 to those who are interested.

What has changed since 1945? Are there today better means of protection from the three-fold threat of the atom bomb? Has it after all been possible to reduce the danger of the "absolute weapon"? Questions which even the least sensitive must ask themselves from time to time and the answers to which are even more urgent now that civilian casualties in World War II have been announced. Even before the atom bomb was used these casualties were appallingly high. In Germany, according to a statement by the Federal Statistical Office at the end of March, 1951, they were about half a million civilians, out of a total casualty list of three millions; in France, President Auriol told the U.S. Congress, there were 112,000 deaths among the civilian population, out of total fatal casualties of 575,000.

Protection from what?

Anything in the way of a detailed description of the effects of the atom bomb would be well outside the scope of this article. Such a description is also hardly necessary, since the daily press, official publications and a steadily growing flood of popular scientific books with the widest appeal have already provided the basic notions.

For the sake of clarity, however, it would be well to recall that the effects of the explosion of an atom bomb take three different forms, two of them being similar to the well-known effects of conventional high explosive bombs:—

1) *Blast*, caused by the displacement of the surrounding air layers as a result of the sudden expansion of the gases formed during the explosion; it causes damage to buildings and physical injuries.

2) *Heat flash:* both direct contact with the flame and heat radiation cause fires and burns.

It must not, of course, be forgotten that the blast, heat and light waves of an exploding atom bomb are more than a thousand times as powerful as the corresponding

The latest American atomic bomb tests were carried out near Las Vegas (Nevada) in February 1951. The sky above Los Angeles 250 miles away was lit up as bright as day by the glow from the explosion.

[1] "*The Absolute Weapon*": Atomic Power and World Order... By F. S. Dunn, B. Brodie, A. Wolfers, P. E. Corbett, W. T. R. Fox. Published by Harcourt, Brace & Co. New York, 1946.

[2] "*The Effects of Atomic Weapons.*" — Los Alamos Scientific Laboratory. Washington, June 1950.

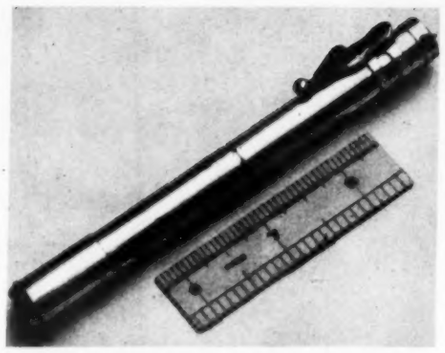
[3] "*Atomic Warfare.*" — H. M. Stationery Office. London, 1950.

[4] "*Atomkrieg. — Wie schütze ich mich?*" — Terra-Verlag. Constance, 1950.

energies released by even the biggest high explosive bombs [5].

Whereas the explosion of a two-ton bomb with chemical explosive charge (TNT bomb) releases a maximum temperature of around 5000°C, the atom bomb produces—though only for tenths of thousandths of a second—temperatures of over 1,000,000°C, in other words temperatures such as have never before been known on earth and have occurred only in the heart of the sun. To the poor wretch who happens to be immediately under the explosion (ground zero) or within a radius of about half a mile it will doubtless be immaterial whether he is struck down by a temperature of 5000°C or by one of 1,000,000°C. However, for the stricken town it is by no means immaterial that the effective range of the heat flash of atom bombs is also greater, so that all life will be destroyed within a radius of half a mile, serious burns will be inflicted up to 1 mile and burns of lesser intensity up to 2½ miles.

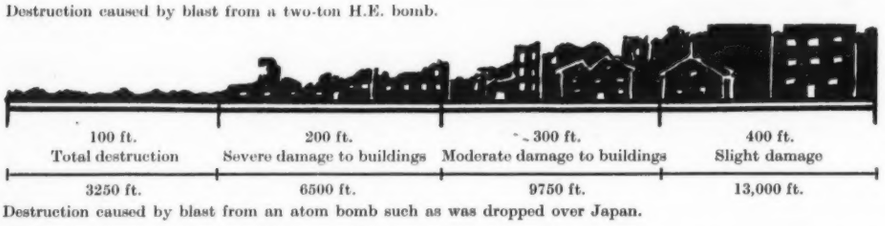
The radius of blast effect is similarly much greater. One of the reasons for this is that the blast from a H.E. bomb lasts only for a few thousandths of a second, whereas in the case of the atom bomb it continues for over an hour.



Radiation counters have been improved and made more compact in recent years. Basically, however, the role they play is merely that of a thermometer which registers the degree of an illness or of radioactive contamination but can do nothing to overcome it.
Left : Pocket dose meter which is carried in the breast pocket like a fountain pen and measures the total radiation dose.

Right (Photo : Crown Copyright) : Portable measuring instrument with which the intensity of gamma radiation is checked in British laboratories, to prevent radiation sickness. The American Committee for X-ray and Radium Protection has calculated that the maximum safe dose for humans per day (for protracted exposure) is 0.1 *r* (*r* = Röntgen). 600 *r* (whole body exposure) is a fatal dose.

Destruction caused by blast from a two-ton H.E. bomb.



Destruction caused by blast from an atom bomb such as was dropped over Japan.

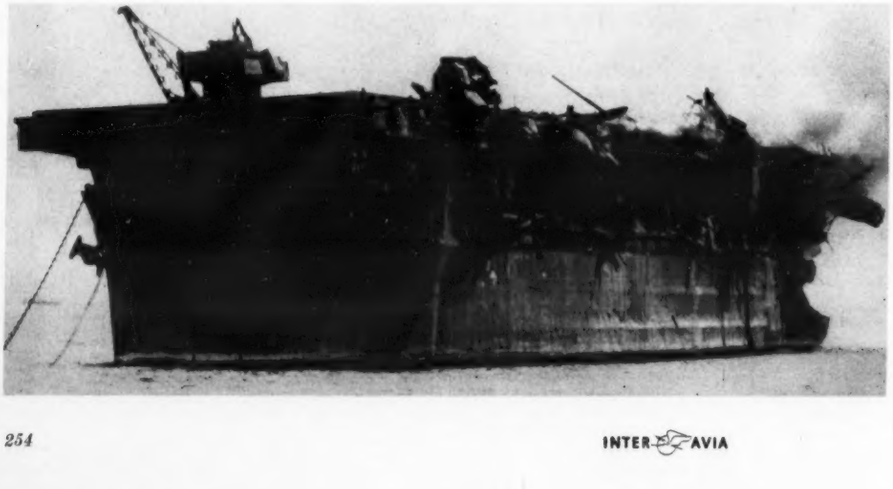
The *third effect of the atom bomb, new and by far the most dangerous* is the *radioactivity* it produces. The immediate danger arises from the emission of gamma rays and neutrons which continues for about a minute after the explosion. According to experience in Japan (height of burst 2000 ft. above ground) a "lethal zone" (100%) must be reckoned with within a radius of about half a mile, with 50% fatal casualties within a radius of 1 mile and severe to slight cases of radiation sickness up to 2½ miles from the centre of the explosion.

But this relatively short irradiation is not all. More serious are the delayed effects of radioactivity, the contamination by radioactive products which fall to the ground, like ashes after the eruption of a volcano, and may affect wide areas for a long time afterwards.

The distance which can be travelled by radioactive dust was illustrated a month after the "Trinity" experiment made at Alamogordo (New Mexico) on 16th July, 1945. On 6th August, 1945, damage suddenly occurred to X-ray films in Vincennes (Indiana), over 1000 miles away, and it was found that the strawboard used as packing was slightly radioactive. It had been washed in water from the Wabash River which flows through New Mexico and Indiana.

[5] The energy of the atom bombs dropped over Japan corresponded roughly to that of 20,000 tons of TNT.

The American aircraft carrier "Independence" which was used in the "Able" test at Bikini and became contaminated with radioactive substances. Not until three years later had the radioactivity abated sufficiently for the ship to be fit to man again.



The length of time the effects of this contamination last was clearly shown by the American aircraft carrier "Independence" which was used in the Bikini test. Even though it was sprayed down immediately with sea water, radioactivity was still so powerful a fortnight later that personnel could remain on board, even with protective clothing, only for the briefest periods. A year after the explosion it had considerably subsided, but was still strong enough to prevent the ship from being manned. It was not until three years after the Bikini test that the carrier was fit for use again, since by that time the weekly radiation dose had been reduced to within the safety limits fixed by the Atomic Energy Commission.

What Suggestions are made?

The list of 25 authors, 14 occasional contributors and 48 advisors who collaborated on the American publication, "The Effects of Atomic Weapons," includes so many outstanding names from the U.S.A.'s best-known research centres that there can be no doubt of the reliability of this work.

Nevertheless the conscientious reader might well begin to doubt when reading the foreword whether the material presented is truly complete and up-to-date. For example, he would come up against the cryptic remark: "Of necessity, classified information vital to the national security has been omitted." Indeed the American publication is based solely on the results of the five atom bomb explosions which took place up to the summer of 1946:—

16th July 1945 Alamogordo "Trinity Test"	Uranium	235
6th August 1945 Hiroshima	Uranium	235
9th August 1945 Nagasaki	Plutonium	239
1st July 1946 Bikini I "Able Test"	Plutonium	239
25th July 1946 Bikini II (Under-water) "Baker Test"	Plutonium	239

All the details given of the effects of the explosion are based on experience of the uranium bomb used in Japan ("nominal atomic bomb") [6]. Since then, however, new

[6] *"The Effects of Atomic Weapons,"* pp. 13 and 24.

atomic weapons have been developed in comparison with which Einstein describes the atom bombs of 1945 as "mere fireworks" and Oppenheimer as "child's play."

*

Has the development of protection and treatment kept pace with the weapons of attack? Has any real progress been made since 1945 in the matter of civil defence against atom bombs?

Instruments for measuring radiation (Geiger-Müller counters etc.) have been perfected and made more practical. The advantage of this should not be under-estimated, since by their aid many people can be prevented from entering contaminated areas and thus preserved from radiation sickness. As a point of interest, pilots at American ports have recently been equipped with pocket counters to prevent the smuggling of radioactive substances into the USA.

But basically radiation meters are merely thermometers which measure the degree of a sickness without doing anything towards healing it. What is the position as regards the real protection of men and material from the effects of heat, blast and radioactivity?

One great difficulty experienced in planning civil defence measures arises from the fact that the three effects of the bomb vary according to the height of the explosion above ground level. In high air bursts the blast effect is more widespread, but the amount of radiation reaching the ground is smaller and delayed contamination less serious (though in part dependent on weather conditions). In low air bursts results are the reverse and for under-water and underground bursts the sources of danger are different again.

A large number of writers in recent years have demanded a radical revision of town planning as a preventive measure against all three dangers: gradual decentralization of large towns with their concentrations of population and vital installations and removal to widely spaced settlements in flat country [7].

Needless to say, the realization of such plans—insofar as they can be co-ordinated with the requirements of modern economic life—would take very many years. No immediate assistance is to be obtained in this direction.

Today efforts are being concentrated on constructing new buildings and strengthening old ones to give a degree of protection, and on the provision of "atom-bomb proof" shelters. Without going into detail it can be stated that the effects of blast and heat waves and, to a certain extent, those of radioactivity can be greatly reduced by strong concrete constructions without windows and virtually overcome by surrounding these with earth embankments.

Measures to protect personnel from the immediate effect of an explosion—wearing light-coloured clothing not easily inflammable, keeping away from windows, crawling under furniture and behind projecting walls, earth embankments, etc.—can, at best, merely reduce the dangers of heat radiation. Up to date there is no adequate protective clothing against gamma rays, nor are any other individual protective measures known.

What of radioactive contamination? It is interesting to note that the American publication begins its section on decontamination measures with the following words [8]:

> "It should be understood that the activity of a particular radioisotope is not changed by any chemical reaction. All the latter can do is to convert the active isotope into a soluble compound so that it can be detached and washed off as a solution."

In other words radioactivity continues in the solution so that the problem is not solved but merely becomes the question of what to do with the solution.

Fortunately, delayed radiation is less penetrating than the gamma rays occuring at the time of the explosion, so that a larger number of preventive measures can be taken, *e.g.*, atom filter (respirator), protective overalls, gloves, rubber or strong leather shoes, the avoidance of eating, drinking or smoking in the contaminated area, and as far as possible keeping clear of heavily contaminated regions.

For the decontamination of personnel, thorough washing with soap, detergents and brushes (being careful not to break the skin) is recommended. Clothing and other objects, if heavily contaminated, should be removed and decontaminated as for chemical warfare agents. Food which is not stored in airtight containers must be destroyed.

From this somewhat summary account it emerges clearly that at present *no really effective remedies* have been found and that the population must continue to make the best of the old methods.

Doctors fare no better in the treatment of radiation sickness. An indication of this is that "L'Arme Atomique[9]," the excellent 416-page book by P.-E. Génaud, a French army medical officer, devotes only 12 pages to actual methods of treatment. He recommends the following treatment in cases of radiation sickness. Complete removal of all contaminated blood; administration of anti-infection preparations (antibiotics); complete physical and mental rest; careful protection from infection; suitable diet. Other methods not yet fully proved include toluidine blue (an antiseptic tar dye), desoxycorticosterone (a hormone preparation) and, to increase resistance, rutin, Vitamin C and Vitamin B6.

No escape?

Naturally we should all feel more comfortable if it could truly be said that the dangers of the atom bomb had been overestimated. In truth, there has been no lack of attempts to belittle the atom bomb. These reached a climax in an astounding pamphlet published in France in 1948 in which the author declares, in tones of conviction, that the statement that the atom had been split was an attempt wilfully to mislead the public. The bombs dropped over Japan were high explosive bombs and the so-called "atom bomb" is a myth ("a farce") [10].

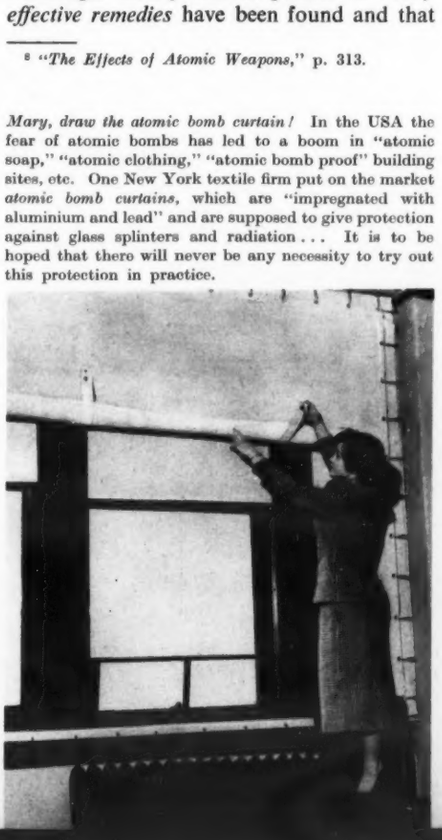
However, this and other similar "explanations" cannot obscure the harsh reality of the atomic age. Those who look facts in the face will have to admit that at the present day very little can be done in the way of civil defence measures against the effects of atomic bombs.

Nevertheless, there is no need for complete despair, now that nations have begun to think about preventive measures.

The appearance of nearly all new weapons in the course of history has produced a shock on contemporary populations who in their immediate despair were prone to believe that no effective defence could be organized. Aeneas, an artificer who lived at the time of Philip of Macedonia (fourth century B. C.) stated in the instructions for preparing his new incendiary material: "To produce a fire *which it is impossible to put out*, take pitch, sulphur, tow, grains of incense, shavings of resinous wood..." And the first large-calibre fire-arms of the Chinese (600 B. C.) which caused a complete panic were inscribed: "I am death to traitors—from me there is *no escape*."

No escape? Again and again man has proved that these words do not exist for those who think coolly and calmly.

Mary, draw the atomic bomb curtain! In the USA the fear of atomic bombs has led to a boom in "atomic soap," "atomic clothing," "atomic bomb proof" building sites, etc. One New York textile firm put on the market *atomic bomb curtains*, which are "impregnated with aluminium and lead" and are supposed to give protection against glass splinters and radiation ... It is to be hoped that there will never be any necessity to try out this protection in practice.



[7] For example, "*Must we hide?*" by R. E. Lapp. Addison-Wesley Press, Cambridge (Mass.), 1949.

[8] "*The Effects of Atomic Weapons*," p. 313.

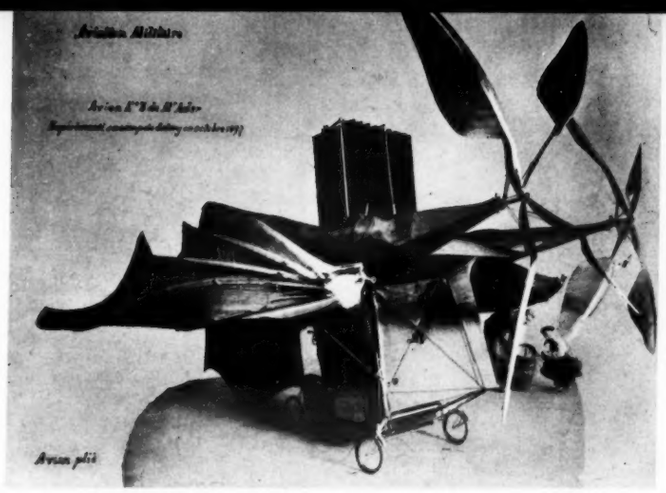
[9] "*L'Arme atomique*" by Médecin Lt. Colonel P. E. Génaud, published by Dunod, Paris, 1950.

[10] "*La Farce atomique*," by Maxime Vincent (second edition), published by Fischbacher, Paris, 1948.

No Wheels—No Runways

BY JACQUES LECARME

EXPERIMENTAL AND FLIGHT TEST GROUP, SNCA DU SUD-EST



Clément Ader's "Avion" No. 3, tested at Satory in October, 1897. Front wheels were fixed, rear wheels movable.

FOREWORD

The writer has not had the audacity to present ideas of his own in this article. He has merely drawn on others. Some of these ideas are quite old—as one measures age in the aviation world—and a number have been successfully put into practice.

In every case the "routine" of "official policy," to put it mildly, caused them to be rejected.

From time to time the writer too has put forward, in his professional capacity, fresh technical suggestions of this nature. Never having been taken seriously he has not been any more successful than the others. This will explain in advance the frankness of his opinions and his occasional digressions.

CHAPTER I

AIRCRAFT WITHOUT UNDERCARRIAGE

1. *EVOLUTION OF THE UNDERCARRIAGE*

We do not claim that in every case in the following review the undercarriage, however excellent in itself, is the best possible one for the aircraft in question. We merely stress that other considerations have led to the use of a less-than-perfect undercarriage.

Clément ADER, the patriarch of pilots, fitted his aircraft with an undercarriage now known as "classic," with fixed front wheels and movable tail wheel.

Following his experiment at Satory on 14th October, 1897, he said: "We saw the ground subsiding... and then moving sideways." Having been driven off the track following a bad landing (reason given, he was in the wrong, since he had no licence), he concluded in 1898:

"Undercarriage wheels will be free and will be able to turn in all directions during manœuvres on the ground; nevertheless, with the aid of a powerful brake, the two front wheels can be blocked, leaving the rear wheel free, so as to bring the aircraft to a standstill and keep it turned into the wind."

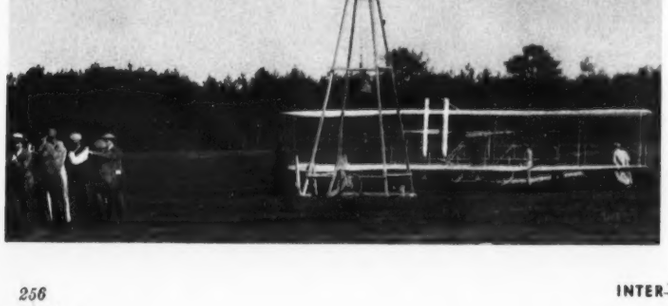
Then the WRIGHT brothers flew. Being Americans, they did not attempt to make a machine in conformity with a "programme" and nobody demanded of them that their machine should do anything else but fly. Their solution of the landing gear problem was intelligent: *a catapult for take-off and skids for landing*. Why carry excess power in flight and equipment which is needed only to wheel the aircraft into the hangar, encumbrances which weigh 20% of the total weight and are used for only 40 seconds during each flight? This far-seeing solution was unanimously ignored, because of short term considerations.

Louis BLERIOT, like Gabriel VOISIN in the first aircraft to fly one kilometre (piloted by FARMAN) in 1907, built his first undercarriages with three wheels. Rear wheel fixed and front wheels movable (synchronized). This was an excellent solution; there is no danger of a crabbed landing and the aircraft is *stable during taxiing, even on slippery ground*. Unfortunately he did not dare put brakes on his front wheels, probably from the same prejudice which caused the installation of front wheel brakes in motor-cars to be postponed until 1925. He therefore put a skid under the tail and fixed the front wheels. From type XI onwards the "wooden horse" was supplied with every aircraft *for the next thirty years*. (N.B. this gives an accurate measure of the "routine" referred to in the foreword). The only remedies tried out were no more than stopgaps such as locking rear wheel, brakes, Goodyear semi-swivelling front wheels.

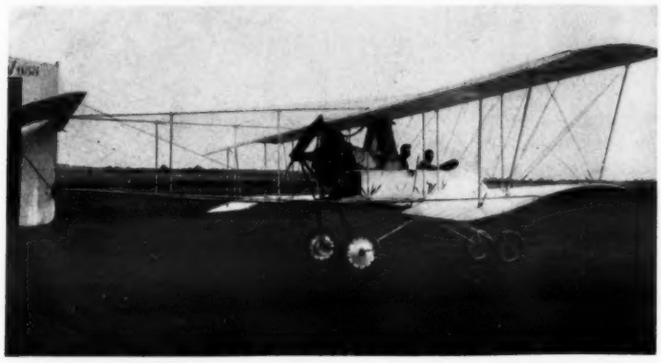
Gabriel VOISIN did a little better. He placed the main load on two rear wheels, *with brakes*, and ensured equilibrium on the ground by means of two front wheels. Because of their low load it was not necessary to make them movable, particularly as the rear engine blew on to a rudder unit which was arranged in the correct direction (rare at that time) and was therefore efficient, so that turns on the ground were simple. No further interest was therefore taken in the VOISIN aircraft.

Robert ESNAULT PELTERIE invented not only the joystick in 1907. His aircraft was fitted with an axial undercarriage (tandem gear) with *movable front wheel*. Light wheels at the wing tips maintained balance when the aircraft was stationary. This type of undercarriage has a number of substantial advantages.

The Wright Brothers used a catapult for take-off and skids for landing. Take-off power was provided by a weight suspended from a pylon and connected with the aircraft by a cable over a series of pulleys. When the weight was released, the aircraft was catapulted away from the pylon along a wooden rail. Note men pulling the weight to desired height in picture at left.



The Blériot IX had a fixed tail wheel and movable front wheels.



Voisin's early types had two rear wheels taking the main weight and two front wheels to maintain the aircraft's angle of incidence.

On the Ground:

— Complete stability in cross winds and drift during landings.
— Constant angle of incidence—the pilot has only to open the throttle and wait, premature take-off being impossible.
— On landing, the angle of incidence is less than stalling angle so that it is not possible to bump no matter what the angle of presentation.
— Lateral and vertical stresses are taken up seperately. The aircraft is stable when braked in a cross wind, even if one of the main tyres bursts.
— The wings, relieved of extra stress, can be thin and without cut-outs. The balancing wheels are easy to instal. All the heavy stresses are borne by the fuselage which must in any case be strong enough to resist bending stresses.
— Since it is of advantage to move the balancing wheels rearwards in relation to the axis of the rear main undercarriage unit (when it would no longer be necessary to make the wheels movable) this system would be admirable for swept wings (B-51).

It may also be noted that this is the system used in seaplanes, two axial floats and two wing-tip floats to ensure equilibrium. Georges MESSIER was not greatly appreciated in 1934. BOEING and GLENN L. MARTIN were more powerful and have been able to introduce a similar system, having recognized its merits, in the B-47 and B-51.

It has thus taken half a century to arrive at undercarriages which are stable in all conditions, even in the event of a blow-out. Only two designers in the whole world have been able to arouse the confidence of their backers and get beyond the paper and the experimental prototype stage. Goodyear has modernised ADER's second undercarriage, with its controllable wheels, but this is only a make-shift solution. It should be noted once more that the only objections raised against these designs were of a purely sentimental nature, and not technical or scientific.

Let us continue however.

— A successful undercarriage accounts for at least 7% of the total weight of the aircraft, not to mention its cost. Now in many aircraft the total payload does not exceed 10%. Here is straight away a means of almost doubling it.

Why has no-one returned to the WRIGHT brothers' system, which in our view is perfect? Especially as nobody has ever dreamt of criticizing a ship because it has to have tugs to tow it into port and bring it alongside. One answer can be found in the following phrase from the French *General Staff's aircraft programme for 1911:* "The aeroplane must be able to take off and land in an *uncut* cornfield without outside aid."

Remarks:

Naturally, as war is waged only in the summer, an aircraft not designed with this in mind would be incapable of military use. The extraordinary thing is that some machines did succeed. L. BREGUET for example.

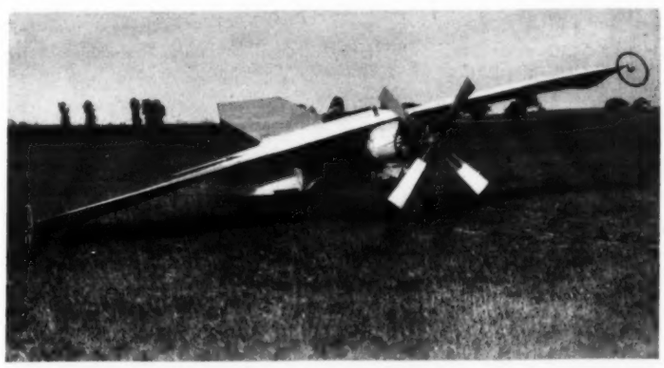
The reader should please not laugh, especially if he has personally assisted in the preparation of aircraft programmes.

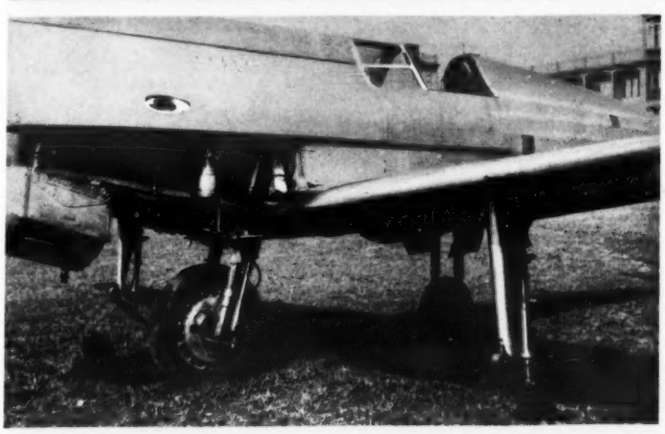
Let us now examine what would be the results of the adoption of the WRIGHT brothers' system.

2. *LANDING*

We shall deal with this case first since it decides how much of the traditional landing gear must be retained. The landing gear is designed to disperse, in the form of heat, the kinetic energy of the aircraft and so bring it gradually to a stop.

For the sake of convenience the total energy is divided into energy paralle to the ground which must be dispersed by a braking system and energy perpendicular to the ground which must be absorbed by a system of shock-absorbers. These two types of equipment may or may not be carried in the aircraft, which gives us a simple classification of the possible solutions.





Three generations of tandem gear: *Top:* Robert Esnault-Pelterie's REP-2, which had a movable front-wheel and two light wheels at the wing tips. *Centre:* Messier, the French undercarriage specialists, took up the idea of the tandem gear in the 'thirties but failed to assert themselves. *Bottom:* the modern triumph—the Boeing B-47 "Stratojet" has a tandem gear. So has the Martin B-51 light bomber.

Energy parallel to the ground—braking

In the aircraft—brakes.

During the days of grass runways and the landing skid, brakes of any kind were a great luxury. Things have changed since then. In general, if the time and speed of landing and take-off remain unchanged, the energy required to vary the speed between zero and the minimum airborne speed in the required sense is also of the same order. *The power to be dispersed by the brakes is almost as great as the maximum power of the engines on take-off.* Also, friction surfaces become more numerous. The number of discs is increased. But the question then is

The Goodyear Tire and Rubber Co. modernized Ader's second gear with its movable front wheels by designing its well-known cross-wind landing gear, here mounted on a Stinson "Voyager" lightplane.

where to get rid of the heat if it cannot be transferred to the wheels and their tyres. The pressure could perhaps be increased, but that raises the problem of providing discs and fittings to withstand temperatures above 500°C. It is difficult to know what to do with this heat.

In 1939 P. E. MERCIER got round the difficulty by filling the hub of the wheel with water. The specific heat of the water and its subsequent evaporation constituted a fairly light-weight safety valve.

The tyres, between the ground and the brakes, also suffer. As the wheels start rotating on impact a good section of the tyres goes up in smoke. Then, since their surface is deformed and strained, the slightest stone or piece of metal makes a cut which gets bigger and bigger. In short a tyre lasts 25 to 50 landings, brakes very little longer and a complete wheel, weighing 5 to 10 tons, costs almost a million French francs (1950). And the deceleration is rarely in excess of 0.4 g.

There are other methods of absorbing this energy. It can be dispersed by means of a yielding substance such as soft earth or water.

In the former case there is friction between the metal of the skid and the ground. Quite considerable speeds can be tolerated, as is shown by emergency belly landings, *e.g.* of 90 to 125 m.p.h. This depends above all on the nature of the ground. The heavy ploughed soil of la Beauce is excellent. The stony ground at Istres is more destructive. But coefficients of friction of 0.5 to 1 with only slight damage are obtained even on non-prepared surfaces. The Lippish Me 163 used this type of undercarriage. Directional stability is good and deceleration tolerable at 0.5 to 1 g.

The second substance, namely water, will be discussed later.

The energy can also be dispersed into the air. There is for example the "air-brake" parachute. This system is

Brakes on the landing surface instead of in the aircraft wheels—arrester cables on the carrier deck, arrester hook on the aircraft (in this case a North American FJ-1 "Fury" of the U.S. Navy).

light in weight — (10 to 20 lbs. altogether for an aircraft of 15 to 30 tons);
economical — a parachute 19 ft. in diameter costs from 50,000 to 80,000 French francs, or ten times less than a single wheel;
efficient — it is easy to get 0.4 g deceleration;
stable — with a well-designed parachute (ribbon parachute, for example) it is easy to keep to the runway, even in a cross wind.

If appropriately constructed it can be opened in flight before landing. The pilot need only fly parallel to the ground and operate the parachute control as he reaches the beginning of the runway. The aircraft is then brought down and braked gently, without *possibility of failure*.

It can be imagined that in a delta wing aircraft the pilot will prefer to approach at a greater speed and a shallow angle of descent, and come down with the aid of a parachute brake, rather than at an angle of descent of 30°, using the maximum lift of his wings, but having the difficulty of absorbing his vertical speed to cope with, with very little time to spare.

Another way is to use the force of gravity as brake, by landing against the slope on an inclined runway. This system is excellent and the aircraft quickly comes to a stop. It is frequently used by gliders. The objection lies in the difficulty of piloting and has just been described above. For this type of landing to be successful, the speed of approach must be higher.

Finally, brakes can be provided on the ground instead of in the aircraft wheels. There is, for instance, the system used on board aircraft carriers, a system of cables on the ground wound on winches, and an arrester hook on the aircraft.

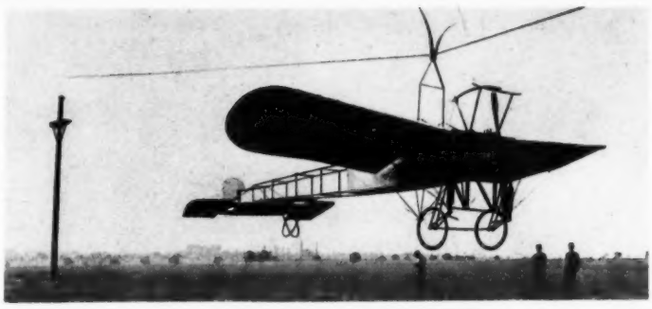
This system is efficient and reliable. It is simple in practice provided the pilot of the aircraft follows implicitly the instructions of the batman on the deck.

It is difficult to understand why this system has never been introduced on land. It could so easily be made mobile by being mounted on special vehicles, either self-propelling or trailers.

Energy perpendicular to the ground

This problem is more difficult because of the inexactitudes in piloting arising from delays in human reactions. In the helicopter, except in cases of emergency and autorotation landings, there is plenty of time to descend slowly. No outside aids are required for landing.

The SNCASE SE. 2410 "Grognard" slows down its landing run by means of a ribbon parachute. Another type of ribbon parachute is visible on the photo of the Boeing "Stratojet" earlier in this article.



A composite system was designed by Louis Blériot and tested by Pégoud in 1912. It also "landed" on the cable by means of the lyre-like device at its top.

The aircraft was suspended from a cable, along which it gathered the necessary flying-speed.

If, however, the risk of breaking the undercarriage in the event of an emergency landing is accepted, a very simple undercarriage can be used (cf. the Bell 47D 3).

Unfortunately the faster an aircraft flies the higher is its landing speed. There is less and less time to "round off," that is, to absorb the vertical energy of the aircraft and give it a trajectory parallel to the ground at low altitude. The margin of error increases. Up to the present aircraft have been provided with shock absorbers, most of them oleo-pneumatic.

Some system of transferring part or all of the work done by the shock absorber to the ground may be tried. The following are possible solutions:—

— an air-inflated rubber pneumatic mattress. This system has been investigated in Britain and tests have been made with the "Vampire." Nothing has been published since these tests, which appeared to be very promising.

— the ground itself—if it does not absorb all, it can absorb part of this energy. This brings us back to the skid.

— water—and the seaplane.

A mixed system was designed by Louis BLERIOT and tried out by PECOUD about 1912. A cable was hung from pylons a certain distance above the ground and the aircraft suspended from it. The aircraft cast off from the cable when it had got up sufficient speed. It "landed" by attaching itself, from below. Special gear was used for attachment, and braking was provided by the cable.

This arrangement would be highly suitable in very broken country for light aircraft, and on board ship. The Americans adopted it in 1942.

3. *TAKE-OFF*

The problem here is relatively simple, since there are no very great piloting difficulties. There is no energy here to be absorbed.

If the aircraft is supplied with a generous amount of excess power it cannot help but fly, and the take-off will be less dangerous than at present. And if the source of the additional power is left on the ground, its weight is of small importance.

The problem therefore is to give the aircraft an acceleration of 1 to 2 g (quite acceptable) and to launch it at a speed sufficiently *higher* than its minimum safety speed so as not to run any risks from breakdown, gusts or cross winds. There are two methods, the take-off rocket, which we shall not discuss here since it is carried on board the aircraft, and the catapult. The latter has scarcely been used except on board aircraft carriers—and then only for short distances and high accelerations. But it would be quite possible to equip bases with long-distance catapults. With runways 650 to 1300 ft. long and an acceleration of 2 to 1 g, a speed of 290 ft./sec. or 200/m.p.h. can be obtained. The Westinghouse "Electropult" lends itself well to such a system. The aircraft can then rest on its own undercarriage and be towed as on present-day aircraft carriers or placed on a trolley if it has no undercarriage.

— Another type of catapult is gravity. By taking off down a slope the length of run is very much reduced. The Germans tried this out on slopes of up to 45°.

4. *POSSIBLE SOLUTIONS*

Having concluded our review along the lines first sketched out by the Wright brothers nearly 50 years ago, what solutions shall we put forward to the problem of reducing the load which has to be carried by the aircraft in the form of a gear capable of supporting its weight during take-off and of absorbing the remaining energy during landing, and the extra power required under safety regulations.

For light aircraft the path has been marked out by the glider, or better still by the *Fouga "Cyclope"* and the *Jarlaud and Bertin "Escopette"*—One retractable wheel, lowered for take-off and for taxiing on the ground. There is no need for shock absorbers, lateral stability is adequately provided by skids, or possibly small wheels, at the wing tips.

This implies, of course, that the propeller will be discarded. But we are in any case only talking about the future.

Aircraft of this kind, weighing between 400 and 4000 lbs., represent an ideal of simplicity and safety.

A more elaborate system has two wheels in tandem, for take-off only, to facilitate movement on the ground (Cyclope CM8 R9). The author would very much like to have, one of these days, a four-seater of this design, fitted with two Turbo-méca jets of 700 to 800 lbs. thrust. He would thus be relieved of many worries such as propellers, engines, weather and choice of ground, since such an aircraft could be housed almost anywhere.

For medium and heavy aircraft, the only difference between civil and military will be in the degree of acceleration they can withstand. With backward facing seats 4 g can easily be borne by the professional, 1 g by the civilian. If need be, passengers could face forwards during take-off and backwards during landing.

Since payload will be almost doubled these minor inconveniences to the passenger can be excused. A good publicity story will sugar the pill. It can then be imagined that for take-off a special trolley, self-propelling, on tyres or rails, would carry the aircraft to the runway. The latter would be 650 to 1300 ft. long, and there would be one only, in the direction of the prevailing wind. There the Electropult would take over the trolley, or the rockets it carries would be armed. The whole would be set in motion, aircraft and trolley, and the aircraft would be catapulted off at *top speed* in a clean take-off with flaps down, at the end of the runway.

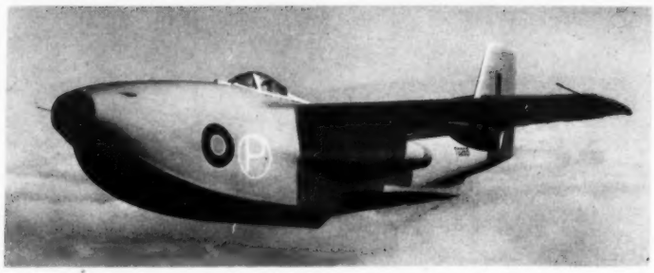
There would no longer be anything to fear from a breakdown on take-off or from high pressure tyres.

For landing there would be a ventral skid with simple shock absorbers, just to take the weight of landing. The runway used would be of clay soil, ploughed periodically, next to the take-off runway.

The trolley, designed to run on all kinds of ground, would come and pick up the aircraft and carry it wherever required. The system of cables such as used on aircraft carriers could be provided if desired.

The Fouga "Cyclope" jet-propelled lightplane. Retractable wheels (without complicated shock absorbing struts) for take-off, skids for landing.

The Messerschmitt Me 323 "Gigant" cargo aircraft had a ten-wheel undercarriage (five in tandem on each side of the fuselage), designed to overcome uneven surfaces like a caterpillar track.



The twin-engined Saunders-Roe SR/A1 flying-boat was the first jet-propelled fighter designed for operation from "limitless" bases, i.e., from water.

For heavy aircraft, with paying passengers, one could afford to be more generous. They could be allowed an undercarriage, but for landing only. This could be of the type of multi-wheel undercarriage with fixed angle of incidence such as was used in the Messerschmitt "Gigant" Me 323 (or in the Arada Ar 232 for taxiing only).

Such an undercarriage with a number of identical parts is well adapted to a high wing and a low-set, easily-loaded fuselage. It is not inevitable that it should be heavy (area compared with volume, or the centipede versus the elephant).

Finally it should be noted that the special trolley, however complicated, and even fitted with rockets or jets, will always be less costly than the present-day undercarriages and the reduction in profitability due to safety regulations, both of which lead in the long run to a reduction in payload.

We must insist on this point, since users have two very different scales of expenses, according as to whether they are thinking of their aircraft or their ground equipment.

We even know of an airfield where, to save electricity, aircraft are sent to another base, for night training.

5. *A NEW TYPE OF BASE ?*

Up to the present landing fields have been restricted to flat ground, preferably, for some unknown reason, in basins at the bottom of a valley. Marseilles aerodrome, for example, would be so much better on the Realtort plateau. And on a plateau the take-off runway can be shortened by constructing it on a downhill slope.

The army could dig passages in the hills, since we are assured that an underground installation is cheaper to construct per square yard than a surface building.

Aircraft could be catapulted along tunnels giving on to the valley half-way up the hillside. They could land uphill on a track covered with soft earth, being braked if necessary by a system of cables and lowered into the ground by lifts, as on board aircraft carriers. A ground organization of this kind would be very difficult to destroy and we should not be surprised if our Swiss neighbours adopted this system one of these days.

Finally, the "zero-length" air base, exemplified by the vertical ramp and guide rails used to launch the German "Natter" rocket-propelled interceptor (pictured).

CHAPTER II

AIRCRAFT WITHOUT BASES

Helicopters already do without bases, except for police restrictions. Could we not do without bases for other aircraft too? Let us be modest in our demands and abolish them only for that category of aircraft which is so essential in these days of cold war, that is, interceptors.

We were discussing this subject one day with a senior officer of the French Air Force, pointing out that on D-day the "enemy" would make a great sweep of all the airfields, where aircraft are lined up in time of "peace" (sic) to help him in identification, and describing the horrors of D-day when none of the aircraft could take off. He replied, quite simply: "But on D-day + 1, I would disperse my aircraft..."

In short, interceptors should not need bases to be constantly on the alert. These are two possibilities: an unlimited base or no base at all.

The former is water. There is no lack of lakes, especilly in France, 600 yds. long and about three feet deep, which is adequate to enable a jet fighter to take off from its hull. The latter should be either reinforced along its keel or fitted with a retractable landing skid, so that the fighter can land wherever convenient, on land or on the water.

A special trolley would come and pick it up. An arrester hook could also be fitted, and a system of cables near its take-off area.

It will readily be admitted that it would be difficult to neutralize a large number of small units permanently dispersed on rivers and lakes, and along the shores. And the question of repairing air bases would not arise. A machine of this kind would have no disadvantages over the traditional types and would gain 8% in take-off load, armament or fuel.

Finally, the base without length would be vertical, like a telegraph pole. This has been tried out once, in connection with the German "Natter" rocket fighter.

The fighters could be housed in garages, hung from the ceiling like bats. Outside in the courtyard there would be a pylon 100 ft. high. The pilot climbs in and the whole is launched. The pilot, being in an advantageous position, could withstand 12 g, which would give a speed of 302 ft./sec. after 0.7 secs. The rocket may or may not be part of the aircraft itself, which may have a turbojet or ramjet engine. A timing device would operate the control to place the aircraft at the best climbing angle.

For landing we should be less demanding than the "Natter," which broke up in the air. We would permit a landing skid and arrester hook and a strip of earth near the hangar, fitted with a cable system.

The two systems outlined above would mean a saving in interceptor units and make them less vulnerable.

Finally we still think that the seaplane, brought fully up-to-date, is the most economical solution for all types of aircraft regardless of weight. But those who still favour seaplanes, seeing in them aircraft as fast as landplanes, more profitable and capable of carrying passengers from *port to port*, using the existing shipping installations, are today regarded as backward.

The Air Hostess Told Us...

COME AND GET IT

Food, says our Favourite Air Hostess, is what preoccupied her throughout the long winter because food keeps out the microbes. Five solid meals a day keep the doctor away. She's feeling fine this spring, she says, thank you. And she's had fun while she worked, for airline meals of today would be a credit to Escoffier (or nearly). Esmeralda suspects that on long distance routes about half the passenger fare goes on food. At Christmas, for example, she was flying from New York to Stockholm to visit some of her friends, and this is what she found on her dinner menu: *Scandinavian Smorgasplate* (a meal by itself); *Roast Turkey and Cranberry Sauce; Salad Waldorf; Mashed Potatoes; Lettuce and Tomato; French Dressing; Old Fashioned Fruit Cake; Coffee.* In a separate paragraph there followed: *Aalborg Taffel Aquavit and Beer; Cherry Heering; Cognac.* Not on the menu were cocktails and an occasional glass of whisky. Sumptuous, hmm? Esmeralda claims that this American-Scandinavian feast was surpassed in her life only once, namely, at an invitation to dine off that old American dish, the celebrated "*Kentucky Burgoo.*" This is a soup composed of many vegetables and meats delectably fused together in an enormous cauldron, over which, at the exact moment, a rabbit's foot at the end of a yarn string is properly waved by a Negro preacher whose salary has been paid to date. These are the good omens by which the burgoo is fortified. Esmeralda has succeeded in spying out the secret formula and gladly places it at the disposal of her friends for use at informal dinners in intimate circles:—

Take 600 lbs. lean soup meat (no fat, no bones); 200 lbs. fat hens; 2,000 lbs. potatoes, peeled and diced; 200 lbs. onions; 5 bushels of cabbage, chopped; 600 lbs. tomatoes; 240 lbs. purée of tomatoes; 240 lbs. carrots; 180 lbs. corn; red pepper and salt to taste, Worcestershire and Tobasco sauce to give it pep. Add squirrels in season. Mix the ingredients, a little at the time, and cook outdoors in iron kettles over wood fires from 15 to 20 hours. Since this recipe will produce 1200 gallons of Burgoo, Esmeralda suspects the squirrel part was the hardest, because you're supposed to use squirrels at the rate of a dozen per 100 gallons. Someone must have had a tough time chasing 144 (or one gross) squirrels. Our Favourite Air Hostess estimates that *one* dozen fat cats caught between midnight and 1 a.m. would have sufficed to give the Burgoo its distinctive squirrel taste. Anyway, after that light dinner Esmeralda concentrated for about one month on another instructive ritual from the Old South, namely, the celebrated *Kentucky Breakfast.* This consists of a large beefsteak, a quart of Bourbon whisky and a hound dog. The dog eats the steak. Recovered, Esmeralda now regards the size of S.A.S. meals as a wholesome average.

NEW SECRET WEAPON: THE RAMMING CORK

Idly leafing through an issue of that amazing fount of wisdom, *The Saturday Evening Post*, Esmeralda came upon an article on America's air power written by an exalted member of USAF brass. Amongst several other deep thoughts she found this: *...Our strategic air power, poised to ram the atomic bomb down the throat of an aggressor in the event it is used against us, has been the cork keeping Communism from spilling over the Democratic nations...*

Make no mistake about it—this is the new secret weapon. What more do you need, asks Esmeralda, than a cork which rams the atomic bomb down the aggressor's throat after he has used it against us? Yet, while some people will claim that reports on Russian aggressive plans merely are red herrings barking up the wrong tree, America would obviously be safer with two corks, for one must never forget that one bird of a feather doesn't make a summer. With two corks, on the other hand, you could easily nip the bull in the bud while the iron is still hot. Just let the airmen do their work without interference, for too many cooks will make Jack a dull boy. It is always better to lock the stable door before the eggs are hatched.

All of us must be unceasingly on the watch, says Esmeralda, to discover (by radar) the snakes in sheeps' clothing and the wolf in the grass and, as soon as the necessity arises, strike the hay by the horns. It will cost money, but it is better to be penny-foolish and pound-wise, and you can't make an omelette without breaking the pitcher that goes to the well. In all walks of life the darkest hour is before the silver lining. With that cork as your ideal, let it be your guiding line that a bird in the bush is worth two bees in the bonnet. And there is always the chance that the Communists are acting on the old adage, People who live in glass houses bark worse than they bite.

FERTILE BRAINS HATCH NO EGGS

Speaking of egg-hatching, our Favourite Air Hostess is reminded of the various plans which experts of the British Ministry of Food hatched and executed after the war. One day they decided that the common or garden variety of hen (it prefers to eat sprouting myosotis, tulip and daffodil buds) would adore living in the Gambia Colony in West Africa and lay eggs like mad out of sheer gratitude and thus relieve the perpetual egg shortage in England. Vast areas were selected, hens were taken to the Gambia in their thousands and luxury coops built all over the place. But, because they were experts, the MoF planners had overlooked the fact that chicken-feed refuses to grow in the Gambia's soil. After they had found out, they decided to drop the whole scheme. Cost to the taxpayer was about £850,000, or nearly £20 per delivered egg! Esmeralda has heard that the hens have meanwhile appealed to U.N.'s International Refugee Organization and are now waiting for rehabilitation.

POCKET CARTOON
by OSBERT LANCASTER

"Now this one will cost more than the Festival of Britain, to build and will make less profit than the Groundnuts scheme, but if we don't like it when its finished, we can always give it to the Foreign Office for an annexe." Courtesy, *Daily Express*, London.

The scheme was a repetition in a minor key of the famous Groundnuts Scheme, which came into being when MoF experts decided to grow monkey nuts on thousands of acres of land in British East Africa. The nuts were then to be crushed to provide the rationed British nation with olive oil, margarine, soap and similar delicatessen. But—the monkey nuts made monkeys out of the planners and didn't sprout. The taxpayer produced about £36,000,000 for expanses of barren land, roads and railways going more or less to nowhere, buildings in out-of-the-way places, worn-out machinery and numerous inspection trips.

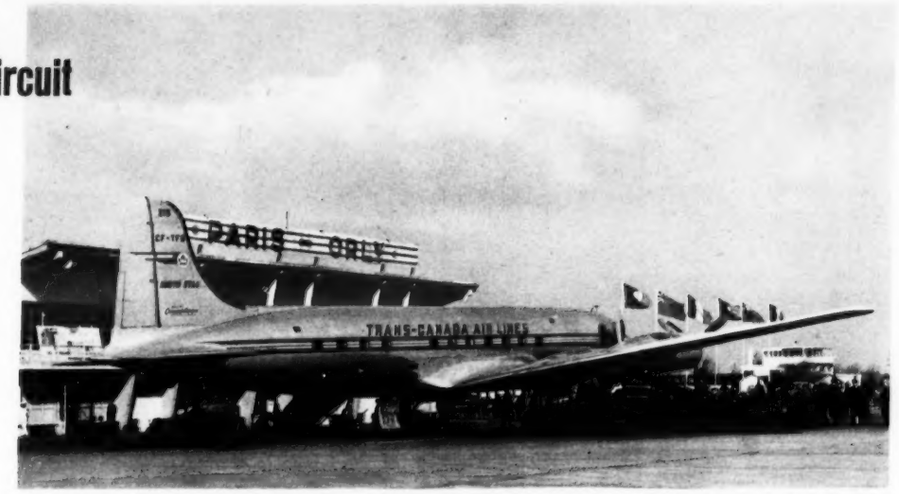
Esmeralda notes that not even aviation has escaped the modern craze for "schemes." There was the Bristol "Brabazon" scheme, providing for the construction of a fleet of huge transport aircraft to wrest the post-war air transport mastery from the Americans. One machine has been completed, the second is nearly finished, but nobody is going to operate them commercially. Cost to the overburdened British taxpayer, between £12 million and £14 million for two aircraft, their giant hangar and runway. Then there was the Saro "Princess" flying-boat scheme, under which a number of large flying-boats were planned for certain overseas routes. The taxpayer will contribute another £5 million to £9 million for the three boats which will be completed, but there is nobody who wants to use them for money-making purposes.

Pity, says Esmeralda, about the Saro "Princesses," victims of our changing times. She likes flying-boats, they are so *very* comfortable. Equipped with a kitchen producing Kentucky Burgoo in reasonable quantities (would you like the "reasonable" recipe?) and fitted with the comfortable chairs of BOAC's Canadair "Argonauts" or Handley Page "Hermes" airliners (the British have always been "seat artists"), our Favourite Air Hostess would not mind flying non-stop around the world in them. The Australians are planning an 8,000-mile service across the Pacific from Sydney to Chile—maybe they could use the "Princesses" to run the world's last long-range flying-boat service and, perhaps, the most comfortable air service of them all?

Failing that, Esmeralda suggests a super-scheme which would consist of rearranging—or "integrating," or "dovetailing" or "co-ordinating," as this essential activity is called today—all the other schemes to turn them into one huge, profitable scheme. This would be run by a special Schemes Corporation supervised by a Ministry of Schemes with thousands of officials capable of turning the Corporation profits into a suitable Ministry deficit. The Corporation would grow monkey nuts in the Gambia (the nuts have always done very well down there: 60,000 tons are exported annually *without* scheme, whereas in three years only 20,000 tons came out of East Africa *with* the scheme). The Corporation would also raise chickens in East Africa. The East African hens would feed on ground nuts flown to them from the Gambia in the two "Brabazons." And the "Princess" flying-boats would be used to carry millions of eggs to the egg-starved Britons—new-laid eggs from Africa every day. Outbound, the "Princesses" could carry hen-inspecting and nut-examining Ministry of Schemes experts, who would fly back home with the eggs. They wouldn't even take up too much egg-space on the return journey. Supposing that the homeward flight of each Schemes Inspector would cost the Corporation £100—well, all he would have to do to is to put five of the £20 Gambia eggs into his pockets to make up for lots value...

T. C. A. Joins the Orchid Circuit

BY RICHARD A. DRAPER, MONTREAL



Trans-Canada's Canadair "North Star" transport lands at Paris-Orly after its inaugural flight from Montreal April 1st.

April was a month of great goodwill between the Republic of France and the Dominion of Canada. France's President Auriol dropped into Canada's capital city of Ottawa to pay his respects to a country that once was a colony of France and where one-third of the population still speak French. Two beavers left Canada to take up residence at the Vincennes Zoo in Paris. A Canadian jazz pianist sent the manuscript of a song called "Ode to Ike" to an American general living in Paris to whom it was dedicated.

As a reciprocal gesture a hull full of French dignitaries and press men hurdled the Atlantic to browse about Canada.

In this effulgent atmosphere Trans Canada Air Lines began its trans-Atlantic service to Paris. A pre-inaugural flight on April 1st carried the beavers and the brass, who went to see Paris in the spring, as well as a junta of newspapermen who went there ostensibly to work.

After this the air line got down to the serious business of picking passengers up in Montreal and putting them down in Paris. T.C.A. began a weekly service between the two cities and plans to increase it to twice weekly during the summer time. Scheduled time from Montreal to Orly Field, Paris, via the United Kingdom is 15 hours.

No newcomer to aviation and international services the Canadian line has been plying its trade for a number of years with little fuss and with reasonable success. The latest extension of its services to Paris involved only small shifts in operations. But the Canadian entry just makes the going a little tougher in the North Atlantic tournament of orchids and champagne.

What with the beavers, the "Ode to Ike" and a common language (the service links the largest and the second largest French-speaking cities in the world), the inaugural T.C.A. service had certain cultural undertones. But it is doubtful whether the hard-headed T.C.A. hierarchy considered this adequate reason for establishing the service. More probably it felt that, despite the frenzied competition to Paris, there would be sufficient traffic in both directions to justify a Canadian service. Air France began service to Montreal on October 2nd, 1950, as provided for by the bilateral agreement between Canada and France in August, 1950.

Whatever the results, it is apparent that the Canadian line will combat the splurge of aerial prizes with the stolid theory that the customer is interested in arriving at his destination on time, that the orchids and champagne are superfluous. Accordingly, T.C.A. customers on the ride to Paris may expect a seat, on-time departure and arrival, food and the solicitude of a steward and stewardess. That's T.C.A.'s idea, anyway, and it will be the rule on the "North Star" passage to the traditional capital of gaiety.

This sober approach is almost a tradition in T.C.A., fostered by a succession of crisp, businesslike executive heads. Not that Canadians are any less friendly than anybody else, perhaps the reverse is true, but the transportation men who have guided T.C.A. in its infancy have been schooled in the harsh economics of surface transportation and are prone to regard the flippancy of latter-day sales promotion as waste of energy and money.

By nature a government-owned enterprise has a more rigid outlook than the private airfarer. There has been little elbow room for histrionics in T.C.A. The only impelling purpose seems to be to provide a high level of technical service with a reasonable measure of economy. There have been those, Canadian and non-Canadian, who have questioned the economic wisdom of a nation of Canada's size (in population) engaging at all in the intricate and costly business of Atlantic air transport.

Gordon R. McGregor, President of T.C.A.

The answer is provided by Gordon Roy McGregor, President: "Without a Canadian airline operating across the Atlantic you can picture the psychological effect... Everybody would think of us as a puny kind of people not big enough to operate our own line in a day when everybody and his brother is flying."

More concrete than the matter of prestige, of course, is the business that follows the flag. It is not so much a matter of whether a medium-sized power can afford to enter international competition as whether it can afford *not* to.

There are two distinct and separate problems for T.C.A.: the domestic routes and the international services. To make this clear for the taxpayer, the line breaks down its annual statement into North American and overseas operations. The annual cost of maintaining Canadian prestige is therefore exposed for all to view. The domestic operations of the line have been conducted normally at a profit. The external services, which were created after the war, have proved relatively costly.

Despite the cost and Mr. McGregor's apprehensions, there is little debate about Canadian achievement in the air. T.C.A. is counted among the ten major operators in the world, along with such giants as P.A.A., B.O.A.C., K.L.M. Royal Dutch Air Lines and Air France. The President claims with considerable justification that "the airline has now reached major stature in Canadian life and is equipped to serve the nation well, whatever the future may bring."

T.C.A. started to serve the nation back in 1937. It began when a Lockheed "Electra" with eight passengers on board took off from Vancouver Airport with Capt. F. Maurice McGregor at the controls. Some 50 minutes and 122 miles later, Captain McGregor (now operations manager of the Atlantic region) touched down at Seattle Airport in Washington State.

On April 1st, 1951, another T.C.A. pilot, Captain Bob Smith, Flight Superintendent, Atlantic Division, marked another milestone in the line's history when he wheeled the

four-motored North Star into Orly Field, Paris.

The Vancouver flight marked the start, the Paris flight the end of the build-up era and the beginning of a period of consolidation. The route pattern of the system has now been pretty well stabilized. The present international network may be considered substantially all the Canadians will seek for some time in the future.

Like most things Canadian the national airline is shaped by a political and economic philosophy mid-way between prevailing sentiment in the United States and the United Kingdom. It combines features of government ownership with some of the characteristics of individual enterprise.

This peculiar hybrid arrangement is understandable when it is remembered that the principal architect of the system has been the Hon. Clarence Decatur Howe, former Minister of Supply, now Minister of Trade and Commerce, a blunt, outspoken, American-born engineer turned politician. It is held that Howe, despite numerous years in politics, is a better engineer and executive than he is a politician. This may account for the relative freedom of the line from political interference. Howe has been considered as the advocate of big business at the higher levels of Canadian government, and has been able to recruit for T.C.A. capable and energetic business men, some from surface transportation and others from aviation circles.

Surprisingly, there has been little political sniping at the "Government airline monopoly"; there have been few serious attacks on the principle of public ownership. There have been few attempts to impale T.C.A. with anything more than political rhetoric, pointed almost entirely to minor defects in equipment. The fact is that the taxpayer is happy with public ownership of the main line and hasn't any plans at the moment to change it. Fortunately for the patrons of air travel, they are in a position where they can compare the standards of American air travel with their own and register whatever protests they have against the Government operation.

The watchdog over the operations of the line is the Canadian Parliament, which is given an annual report. The responsible minister is called upon to answer questions on T.C.A. at any time. A Government-appointed board of seven, chiefly businessmen and industrialists, controls the larger destiny of the line. There are no civil servants on the payroll.

Government ownership and control over airline development springs from what is virtually a phobia with the Canadian people. Canada has a costly duplication of trans-Continental railroad systems, one of which is private and the other Government-owned. The Government has taken great pains to assure against a repetition of competing trunk lines in the air. When the Government decided to create a trans-Continental air line, it called in two private concerns, Canadian Pacific Railways and Canadian Airways, Limited, and offered them participation in the new enterprise. The two companies disagreed on terms and the Government went singly into the airline business.

T.C.A. has its own headquarters in the new International Aviation Building, Montreal, which houses world headquarters of I.C.A.O. and I.A.T.A.

Political responsibility for building the system was handed to Clarence D. Howe, then Minister of Transport. With laudable foresight Howe cast around in the United States for an operating head for the new line and came up with the late Philip G. Johnson. Johnson, one of the ablest people in the air transport business, was President of Boeing Airplane Company and had headed United Air Lines. As Vice-President in charge of Operations he drew up the future blue print of Canadian main line aviation.

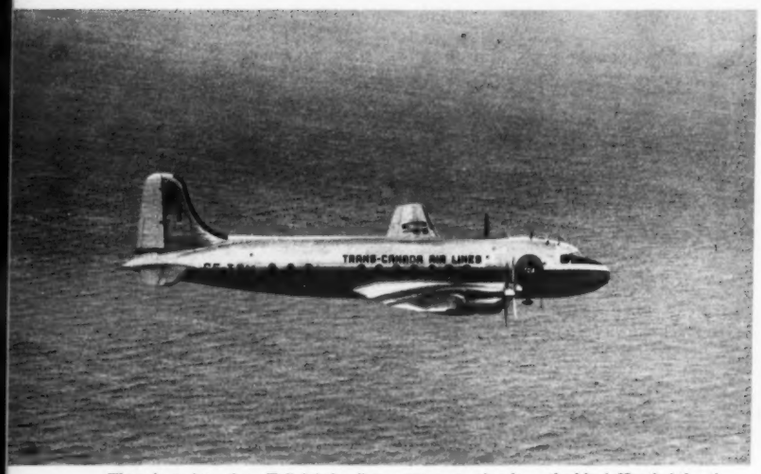
The job, by every token, was an airman's dream. With substantial backing of the Canadian Government he could and did adopt whatever techniques he wished, use whatever equipment he considered best and employ whatever personnel he required. Building a trans-Continental airline from the ground up was a job to challenge the imagination and skill of a man of Johnson's calibre.

There was an unsurpassed variety of terrain and weather conditions. There were formidable Rocky Mountain peaks towering 10,000 feet, along the flight route; there were the interminable prairies, the desolate rocky stretches of the North, the flat farmland of the central provinces and, finally, the Maritime Provinces. There was heat, there was cold, there was ice and fog. But in this land of great distances and difficulties the airplane had proved of incalculable worth. It had opened up the vast, mineral-rich hinterland that rolls up to the Arctic horizon. Air freight, ranging from candies to cows, from beads to boilers, had pushed the fringes of civilization steadily northward.

Pre-war commercial air transport activities in Canada were pretty much catch-as-catch-can. Southward in the United States the airline industry had reached its greatest development, and T.C.A., under Johnson's direction, borrowed liberally from American equipment, techniques and personnel. There is still a heavy imprint of these early influences upon T.C.A. operations. But the majority of the original American personnel has departed, leaving the Canadians, the bush pilots, the young air force veterans and the administrative staff trained in T.C.A. ways.

On April 1st, 1939, Montreal and Vancouver were linked by air. On May 1st, 1942, T.C.A. spread its service to Newfoundland, then a Crown Colony of Britain, now the tenth Province of Canada. On July 22nd, 1943, at the request of the Canadian Government, the line began an overseas mail service to Canadian troops abroad. This service, operated by T.C.A. personnel throughout the war, laid the groundwork for the post-war overseas service. It was operated with "Lancastrians," converted Avro "Lancaster" bombers, until the first "North Star" was put into operation on April 15th, 1947. On May 1st, 1948, the line began a service to Bermuda; another to the Bahamas, Jamaica and Trinidad on December 2nd, 1948. The Caribbean ser-

T.C.A.'s standard long-range transport, the pressurized Canadair-Four, or "North Star," which is a successful cross-breed between the Douglas DC-6 and the DC-4 and powered with Rolls-Royce "Merlin" liquid-cooled engines. Span is 117 ft. 6 inches, all-up weight 78,000 lbs.



There is variety along T.C.A.'s far-flung routes, ranging from the bleak North Atlantic . . .

. . . to the smiling countryside of Eastern Canada . . .

vices were broadened, New York, Tampa (Florida) and St. Petersburg (Florida) were added to the international services.

At the end of 1950 T.C.A. services totalled nearly 17,000 route miles. There were 8,300 route miles on North American services, 8,400 route miles on overseas services. Personnel totalled over 5,000, of which 350 were pilots, navigators and radio officers.

The company's executive offices are in Montreal, terminus of the North Atlantic service. The main overhaul base is at Winnipeg, mid-way point on the North American system. There are maintenance bases at Dorval (Montreal), Toronto, Vancouver, Edmonton and London, England.

Like the Canadian policy of ownership, T.C.A.'s equipment is a mixture of American and British. The North Star, adapted by T.C.A. engineers, is virtually a cross between the Douglas DC-4 and the DC-6 but is powered with British Rolls-Royce "Merlin" engines. The "North Stars" were manufactured in Montreal by Canadair Ltd., which itself is a mixture (it is U.S.-controlled), and are used on all international routes and on long domestic services. DC-3s are used on inter-city and short-stage flights. There are 20 "North Stars" and 27 DC-3s in service.

Apart from the protection given T.C.A. along the main trunk line, aviation services in Canada are competitive. The Canadian Air Transport Board, which regulates domestic air traffic, is liberal with its franchises and grants them whenever it is considered in the public interest and convenience. While the Government has been an ardent champion of an international body with mandatory powers to regulate international traffic, it does not itself insist that Canada be represented on the international routes by a "chosen instrument." Canadian Pacific Railway operates a service to the Orient. Thus the lion of private enterprise and the lamb of State control lie down together tolerantly, if not serenely.

Beavers and Skylarks

Inaugurations of new air services are like happy peoples—they have no history—or rather, when they are trans-Atlantic services, their only history is that of the route they follow. It was like this with the first flight by Trans Canada Air Lines from Paris to Montreal on which I had the privilege to be a passenger. This new service was not really such a great adventure for the Canadian company since it had already been crossing the Atlantic for several months on its Montreal-London service.

There are bonds of very long standing between the Canadians and the French. On its first trip to Paris the Canadair-Four "North Star" brought, in addition to its full load of passengers, a gift for Parisians—two beavers, Mademoiselle Valentine and Monsieur Baptiste, very much alive, who were then taken off in a special bus to the zoo to join their confreres...

Paris replied by sending two skylarks, Francis and Caroline, in a magnificent gilded cage decorated with the colours of the capital—poor creatures, they doubtless had never heard of the charming Canadian song "Alouette, je te plumerai !" However they, like the other French passengers, appreciated at their full value the punctuality and fine service of T.C.A. (though they prefer plain water to whisky!) and the northern route, with the snow-capped hills of Scotland, the sparkling lights on the fishing boats, the dazzling splendour of the aurora borealis... all these were baptised in turn on this maiden voyage:—frozen seas, starry sky and fireworks!

The Atlantic routes will soon be as busy as the Metro (a day when there is no strike!) or the subway. At Shannon, Prestwick, Meeks, the Azores, Gander, passengers are embarked and disembarked by Constellations, Canadair Fours, DC-6s and Stratocruisers. It is seldom one does not recognize a familiar face entering or leaving a Sabena, Air France or T.C.A. aircraft. For instance at Goose Bay, Labrador—which is not exactly a village—I met Dr. Warner, president of I.C.A.O., who was returning from London to Montreal, also by Trans-Canada Air Lines.

Montreal, housing I.C.A.O. and I.A.T.A., is the capital of the aeronautical world, and when we arrived, punctually to the minute, we were received by Sir William Hildred, S. Thouvenot, Ralph Cohen, Henri Bouché, Roper, Boussard, etc., from these two great international organizations, and of course by all the heads of T.C.A., not forgetting their famous pair of Public Relations Officers, Jean Marion and Mike Hildred.

Georges Février

The two larks which sang their way across the Atlantic from Paris to Montreal are being handed by André Thirion, Vice-President of the Paris Municipal Council *(left)*, to Dr. Leon Lortie, Montreal City Councillor.

. . . and the Canadian Rocky Mountains.

T.C.A. executives, like President Gordon Roy McGregor have been trained in private business and retain their individualistic outlook. McGregor is a quiet, sober engineer. He directs the line's affairs with competence and a complete lack of drama. His capacity for self-effacement has hidden some rather remarkable facts about him. For one thing, at the age of 39, when most airmen are chairborne, "Old Gordie," as he was called, was hurtling through the air in the Battle of Britain as a "Spitfire" pilot. He was probably the oldest fighter pilot among the Allied air forces, certainly in the British air forces.

Before the war he earned his keep comfortably if unspectacularly as an engineer with the Bell Telephone Company. He became a very proficient week-end flier and was a member of an auxiliary squadron. McGregor, along with other aging Saturday soldiers that comprised the squadron, was hustled overseas to help the Mother Country in her fight against the *Luftwaffe*. For bringing down five German aircraft and sharing in the destruction of a sixth he was awarded the Distinguished Flying Cross.

By D-Day he had risen to the rank of Group Captain and was in charge of the complex arrangements for moving a fighter group from Britain to the Continent. On D-Day-plus-four McGregor took Group 83 to France, the first Allied air unit to cross the Channel. For this effort he received the Order of the British Empire and attracted the attention of Herbert J. Symington, then President of T.C.A., who was looking forward to the day when he would be able to lay down the responsibility.

His selection of McGregor was unexpected in many ways. It was known that Symington had definite, if unpopular, views on converting military fliers to air transport work. He declared publicly that he would rather train a complete novice for air transport work than re-train a military flier. Despite the swarms of legionnaires and wartime airmen that buzzed around Symington's ears he stuck to his guns. But when it came to his successor he picked... ex-fighter pilot McGregor.

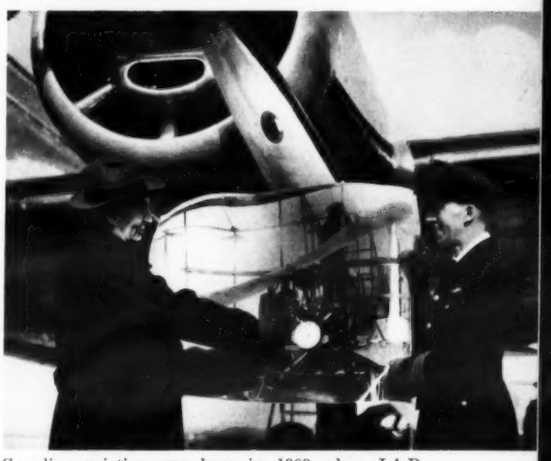
The organization that Symington handed over to McGregor was a going concern, run with precision and orderliness though perhaps without eclat. Symington, a top-drawer corporation lawyer and an experienced transportation man, had soundly and well laid the foundation of the line. It had in fact, become a national institution with wide ramifications. It had become involved in large-scale immigrant transport schemes and exerted its influence upon industrial development and defence planning.

T.C.A., the national airline, is now carrying the flag to various parts of the globe and displaying the Maple Leaf on world air routes. The operation of these airlines has produced very tangible benefits, such as a stimulation of industry and an increase in Canada's defence potential. A pool of civilian aircraft is a useful thing in a military emergency, and so is the trained personnel attached to the organization. Some 70 per cent of T.C.A. captains are former bush pilots and have a knowledge and experience of Arctic flying conditions.

But perhaps most valuable by-product has been the impetus given to Canadian manufacturers of aircraft. The "North Star," mainstay of the T.C.A. fleet, was built largely to T.C.A. specifications. This order sustained the Canadair, Limited, plant in Montreal during the lean post-war years. Now, this plant is making the North American F-86 "Sabre" jet fighters for the Royal Canadian Air Force and NATO countries. T.C.A. engineers also co-operated in the drawing up of specifications for a jet transport. The Avro factory that made this transport plane, the Avro "Jetliner," is now turning out the "Canuck" all-weather jet fighter and a jet engine of Canadian design.

The focal point of most dissatisfaction with the national airline is inevitably the cost of running the service. In Canada the fact that the trans-Continental line has yielded large dividends in telescoping vast distances and speeding up the tempo of industrial and commercial intercourse has sweetened only slightly the pill of annual deficits, though it must be conceded that the deficits are not very great. In 1950, with volume at an all-time peak, the line reported a deficit of about $1.5 million on international services and a small profit on North American operations. This followed a peak over-all deficit for the preceding year of $4.3 millions. Accounting for large post-war deficits has been the putting into service of new equipment and substantial expansion of services. Expectation of diminishing deficits henceforth has been voiced by President McGregor: "It is hoped that this brings to an end the very difficult financial period through which the airline passed in the aftermath of World War II."

To help it to overcome its deficits, the Canadian airline is committed to the struggle for passengers. The extension of its services to Paris is evidence that Canada does not wish to be considered puny. It will endeavour to counteract orchids and champagne by applying the practices it has adopted on its North American trans-Continental routes —prompt departures and on-time arrivals.



Canadian aviation was born in 1909 when J.A.D. McCurdy of Ottawa flew the "Silver Dart," creation of himself and Alexander Graham Bell. Early in 1947 he witnessed the inaugural of the T.C.A.'s "North Star" airliner. He is posing (left) with a picture of the "Silver Dart."

T.C.A.'s main overhaul base is located at Winnipeg, Manitoba. Picture shows a section of the engine shop, with Rolls-Royce and Pratt & Whitney engines undergoing overhaul moving side-by-side along the assembly lines.

1951 Aviation Prospects*

The Hague : typical canal scene.

Netherlands

AIR TRANSPORTATION

The Hague, April. Although K.L.M. Royal Dutch Airlines has not recently expanded its air fleet and operates with a reduced staff, the company has found ways and means of increasing some of its frequencies and inaugurating a number of new services in 1951. Its 68 airliners are linking 73 cities in 56 countries, and K.L.M. has succeeded in integrating its intercontinental and European services in a manner ensuring prompt connections at most points.

K.L.M.'s 1951 programme provides for the operation of cheap European night air services in cooperation with foreign lines. In addition the company is paying careful attention to the German air transport market: Stuttgart will be the sixth German city to be incorporated in the Dutch air transport system; Munich has direct K.L.M. connections to the South of Europe, Indonesia and the U.S.A. Other points on the K.L.M. programme are an intensification of services to the Near East (Damascus and Beirut) and an expansion of its cargo operations. Production of ton-kilometres is to be increased to an estimated 220,000,000 in 1951 from 190,000,000 last year.

SERVICE AVIATION

A precisely defined expansion plan is to be initiated by the Dutch Air Force during 1951. By the end of 1954 the Air Force intends to have 21 combat squadrons, one transport squadron, several reconnaissance and artillery observation squadrons. In other words, the Air Force is to undergo an eight-to-tenfold expansion within four years.

With U.S. help, a tactical air force is to be created in 1951. Extensive local and international air exercices are scheduled for the year in cooperation with the U.S.A., Britain and other nations, and training will be expanded.

The first Republic F-84 "Thunderjets" delivered by the U.S.A. will go into service with the Dutch Air Force in 1951. A "Sea Fury" and a "Firefly" squadron of the Dutch Navy will serve with the British Royal Navy, and additional American and British naval flying equipment is to be supplied to the Dutch in the course of the year.

AIRCRAFT INDUSTRY

Activity at the plants of the famous *Fokker* aircraft company has constantly increased in the past few years. The factory which was destroyed during the war has been rebuilt, and an additional, large plant has been completed at Schiphol Airport, Amsterdam. The latter will be officially inaugurated in May. The new plant is building Gloster "Meteor" fighters for the Dutch and Belgian Air Forces and houses the vast overhaul and repair shops now working for Dutch, Belgian, Swiss and Israeli customers. The old plant is producing Hawker "Sea Furies" and Fokker S.11 trainers and engages in the development of new types.

Since the war Fokker has developed the S.11, S.12, S.13 and S.14 trainers (the S.14 is a jet) and the F.25 four-seater private aircraft (of which 20 have been built), and the company is now reported to be designing a twin-engined turboprop airliner for K.L.M.

Aviolanda, Holland's second aircraft company, continues to build parts for the Gloster "Meteor" and engage in aircraft overhaul work.

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* Concluded from "Interavia, Review of World Aviation," No. 3, 1951.

Brussels : the *Grande Place*.

Belgium

AIR DEFENCE

Brussels, April. The Belgian Government proposes to spend 15.5 percent of its total budget on national defence during fiscal 1951, and one-fifth of the total defence allocation will be spent on air defence. In the Ordinary budget, air appropriations figure at Belg. frs. 1,297,849,000, whereas the Extraordinary budget includes frs. 1,347,024,000 for the Air Force, making *total air appropriations of frs. 2,644,873,000 for the fiscal year 1951.* This is a substantial increase over the frs. 1,783,500,000 allocated to the air arm in 1950.

The Air Force today is about 10,000 strong, including 600 officers and 1,600 N.C.O.s; first-line air crews number 450 officers and N.C.O.s. Training is conducted at three flying schools (200 students) and one technical school (550 pupils). In addition, flying personnel is being trained in the U.S.A. and Canada, ground crews in France, Britain and the U.S.A.

A plan is under way to double the combat strength of the Belgian Air Force. Day fighter squadrons are at present equipped with Gloster "Meteor" jets and soon will receive Republic F-84 "Thunderjets" under the American Military Assistance Programme. Night fighter units still operate de Havilland "Mosquitos." There are two Douglas "Dakota" transport squadrons, an auxiliary fighter squadron for reserve pilots and one Army cooperation squadron (artillery spotting). Training is conducted with Stampe S.V.4B biplanes for elementary training, North American "Harvards" for basic and Supermarine "Spitfires" for advanced training.

An important air base is being established in the Belgian Congo Colony. This is at Kamina, in Katanga Province, between Stanleyville and Elisabethville. Situated at about 3,500 ft. altitude in an excellent climate, the field will have two runways measuring approximately 1.5 miles. Kamina will house the Air Force's advanced flying school and a technical school and will be at the disposal of the Army for training purposes.

AIRCRAFT INDUSTRY

To a certain extent the Belgian Air Force can rely upon the national aircraft industry. *Fabrique Nationale d'Armes de Guerre* at Herstal is producing R.R. "Derwent" jets for the "Meteor" fighters. "Meteor Mk-8" fighters will soon be assembled in quantity at the plant of *S.A. Belge Avions Fairey* at Gosselies, which already repairs and overhauls aircraft for the Air Force. *Sabca* also does overhaul work, and *Stampe-Renard*, which built the S.V.4B trainers, is maintaining them.

AIR TRANSPORTATION

Sabena, the national airline, is adapting its services as closely as possible to the nation's economic requirements. The company operates five Douglas DC-6s, seven DC-4s, six "Convair-Liners" (two more are on order), 19 Douglas DC-3s, seven Douglas "Dakota" cargo transports, four de Havilland "Doves," two Bell 47D-1 helicopters and six miscellaneous types, making a total of 56 aircraft.

The two trunk lines of Sabena's system are Brussels—New York and Brussels—Belgian Congo—Johannesburg. On the New York run the company is flying five services a week, on the African route another five, including three to Johannesburg, one to Stanleyville and one to Elisabethville. In Europe, Sabena will intensify its operations to the major capitals, and—like K.L.M.—the company is paying considerable attention to its connections with German economic centres (Cologne, Frankfurt, Hamburg, Munich). Furthermore, the line is intensifying its European cargo services and expanding its local operations in the Congo Colony. Finally, Sabena is pressing forward with its helicopter mail experiments for the Ministry of Communications.

Sobelair, the privately owned Belgian carrier (capital: Belg. frs. 18,000,000), continues to operate charter services for passengers and cargo between the mother country and the Congo Colony.

Spain

Madrid, April. Important progress was made in various fields of Spanish aeronautics last year and further improvements are expected in 1951. Spain's entry into I.C.A.O. and the recent I.A.T.A. conferences in Madrid have helped a lot in giving new courage to Spanish aviation which still has to struggle very hard to keep its head above water.

AIR TRANSPORTATION

One of the branches of Spanish aviation which has proved that difficulties can be surmounted is the national air line, "Iberia."

This company is operating on internal routes at the lowest rates in the world. "Iberia" charges 370 pesetas (about £4.12s.0d.) for the Madrid-Barcelona flight, compared with B.E.A.'s fare on the London-Edinburgh route (same distance) of £8.0.0d. The company is also the European record profit-making airline. In 1947 net profit was five million pesetas, in 1948 twelve million pesetas, in 1949 nineteen million and more than 20 million was reported for 1950. A portion of the profits is allocated to an equipment replacement fund which at present totals more than 60 million pesetas.

Of the two Spanish charter companies, C.A.N.A. (Compania Auxiliar de Navegacion Aerea) ceased operation some time ago and is now being liquidated. The other, Aviacion y Comercio, continues to grow and last year opened new routes to Southern France and French North Africa.

AIRCRAFT INDUSTRY

The aircraft industry has entered a phase of expansion as a result of the construction of new prototypes by Spanish manufacturers and the installation of new factories; a new propeller factory was inaugurated last December.

The most important prototypes in progress are the C.A.S.A.-202 "Halcon" fifteen-seater transport powered by two Elizalde "9c-29-750" engines of 775 h.p. each for take-off, now nearing completion, and the IBERAVIA I-11 two-seater lightplane which is ready and only awaits its 85 h.p. Continental engine to start its flying trials. The latter aircraft has side-by-side dual controls, a gross weight of 680 kilos, a top speed of 196 km/h. and is fitted with tricycle undercarriage.

SERVICE AVIATION

It is difficult to forecast the future of the Spanish Air Force prior to the solution of certain political problems still pending between Spain and other nations. Although the Spanish Air Force at present is equipped with obsolete aircraft (Messerschmitt Me-109 F fighters, Heinkel He-111 and Dornier Do-17e bombers, etc.), it has good training centres and several flying schools operating good primary and advanced trainers, some of Spanish design and manufacture. These have trained and are maintaining a considerable reserve of pilots and specialised personnel who in case of an emergency would no doubt be useful and relatively easy to train to modern "jet standards."

Australia

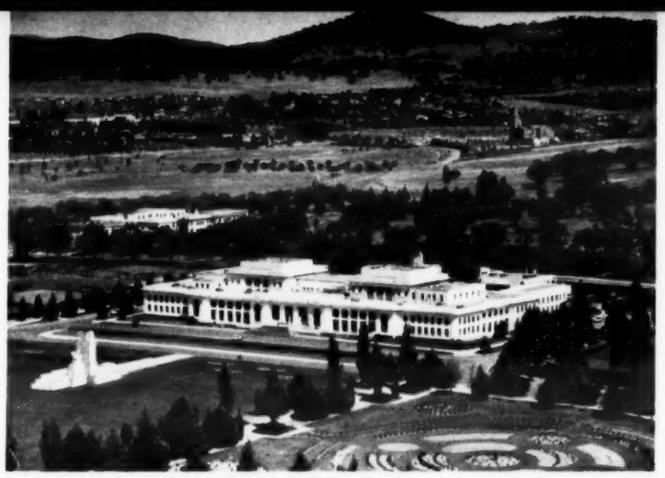
Melbourne and Canberra, April. Heavy emphasis on defence with a consequent, though not necessarily equivalent, lessening of civil development appears as the principal factor governing Australian aviation in 1951.

AIR FORCE PROCUREMENT AND INDUSTRIAL PROGRAMME

On the defence side the picture is one of hurried progress. The demands of the Air Force for modern equipment and more men are pressing, particularly as illustrated by participation in combat operations in Korea where one R.A.A.F. squadron is serving, and in Malaya where two are based. In the 1950-51 Budget the R.A.A.F. received the largest of the additional grants to the fighting services. In this the total expenditure for 1949-50 has been exceeded by £A 11,734,452, raising the current total to £A 23,623,000.

In fighter aircraft, the de Havilland "Vampire" programme, though continuing, is now clearly dated and insufficient in terms of production. Though valuable for jet operational training, the "Vampire" has obvious limitations and, as a step forward, the "Meteor Mark VII" has been ordered for "immediate" delivery to replace the "Mustangs." Under the influence of the Air Staff's interpretation of the lessons from Korea, the Government has now revised its plan to build the Hawker P.1081 in Australia, and while the Federal Cabinet is still non-committal, it is possible that, at the urgent request of the R.A.A.F., the construction of the North American F-86 "Sabre" may be undertaken by the Commonwealth Aircraft Corporation. But this is a thorny question, the largest thorns being British Commonwealth relations and the problem of meeting dollar expenditure. The so-called "realists" advocate adoption of the "Sabre," underscoring the outspoken comment of former U.S.A.F. Commander in the South West Pacific, General George Kenney, in September last, that Australia should build American-designed aircraft and concentrate on fighter and attack types. The opposition comes from those who advocate adherence to British Commonwealth cooperation and co-ordination.

The Escorial, Madrid.



Canberra, Australian Federal capital: the Federal Parliament House.

On the bomber production side the "Lincoln" programme continues, with its cessation determined by the readiness of the State-operated Division of Aircraft Production to undertake the building of the English Electric "Canberra," tooling up for which began several months ago and is now reported to be well advanced. As 1950 closed the Government announced its decision to buy outright from Britain a number of "Canberra" bombers to meet operational training needs and help cover the lag in delivery from the Australian factory. Purchase of a number of long-range patrol-bomber aircraft has been agreed to and the Lockheed P2V "Neptune" chosen. Another urgent need of the R.A.A.F. is heavy transport aircraft about which no official announcement has yet been made.

The R.A.A.F. is also in need of a new trainer aircraft. The Commonwealth Aircraft Corporation has a prototype of an Australian designed trainer—the CA-22—ready for final tests which are listed to take place this spring. If substantial orders are placed by the Air Force, as may be expected, the CA-22 will replace the redoutable 14-year-old "Wirraway." To a query as to whether the de Havilland "Chipmunk" would not meet this need, Air Minister White punned in answer: "What we need most is a 'Cheapmunk'." An order for a number of Sikorsky S-51 helicopters has been placed for the R.A.A.F.; the objective is to have at least one of these aircraft in each State.

GUIDED MISSILES

Development of the Woomera base for guided missile research, using the "dead heart" of the continent for its full-scale range, may be expected to make advances in 1951 under the stimulus of direct British cooperation and the keen interest of the United States. Late in 1950 an Australian-designed and built pilotless jet aircraft powered by an Armstrong-Siddeley "Adder" engine was test flown from Woomera. No further announcement of progress at the range, or in aeronautical research generally is likely for the present.

INTERNATIONAL CIVIL AVIATION POLICY

In administering its civil aviation policy the Government, which entered 1951 after exactly one year's occupancy of the Treasury benches, has in general, continued the policies developed in the immediate post-war years and continued the expenditure of large sums of money on the improvement of ground facilities. The lifting of aviation fuel rationing in 1950 has meant that airline operations are limited only by the size of aircraft fleets since the Government is willing to grant airline licences more freely.

In the international field there is readiness to enter into bilateral agreements with countries wishing to be linked to Australia by regular services. Captain P. G. Taylor, famed Australian pilot-navigator, has just completed a survey flight between Sydney and Santiago, by way of Easter Island; a flight which had the official blessing of the Australian Government. The long-promised direct service across the Indian Ocean linking Australia and South Africa is expected, perhaps somewhat optimistically, to begin in 1951.

DOMESTIC CIVIL AVIATION POLICY

In the domestic sphere the Government is putting into practice its declared intention to give no preference to the nationalised airlines. Straws in the wind have been the withdrawal of QEA's service to Lord Howe Island, giving a monopoly to the privately owned Trans-Oceanic Airlines, and the cancellation of the Government-owned Trans Australia Airlines' licence to fly to the Woomera guided missiles base—a lucrative service which has been given to Guinea Airways, virtually a subsidiary of the privately owned Australian National Airways. A.T.A., too, is showing that it can operate not only with economic success but with top grade efficiency and safety. In the quarter ended September 30th, 1950, T.A.A. actually carried more passengers than the old established, privately owned A.N.A. which, in turn, has developed its freight carriage to double that of T.A.A.

Whether as a Government "feeler" or a self-imposed mission, Air and Civil Aviation Minister White is now preaching the gospel of the part-Government, part-private corporation. There are those who see in the Government's aviation administration an intention to turn T.A.A. into a Government-cum-private-investment corporation as soon as possible. On the other hand, the recent

addition of 5,000 miles of feeder services (which no other airline wanted) to T.A.A.'s route mileage, points to the use of the nationalised airline for development purposes.

AIRPORTS AND AIRWAYS

As an indication of how the defence programme has checked long-range plans for the improvement of ground facilities, the estimated authorised expenditure on new airports is more than £10,000,000, but less than £2,600,000 will be spent this year. The department began the year with a carry-over of £3,600,000 in unexpended funds from the previous year, a sum included in the £10,000,000; in other words, in 1950-51 it will not be possible to catch up with the work authorised for 1949-50. Similarly the Division of Airways carried over £4,000,000 and planned an additional £4,000,000 worth of work for the current year. Despite this delay, good work is being achieved. The number of V.A.R. ranges is being doubled, Omni Ranges are being installed at the busiest airports and the installation of a variety of other flying and landing aids is proceeding.

Canada

Montreal, April. Canadian aviation has engaged in a process of development in 1951 which, in the opinion of service personnel, civilian aviation authorities and aircraft manufacturers, may well be historic.

AIRCRAFT INDUSTRY

The year 1950 was one of continual progress, but 1951 bids fair to outstrip it. And back of the progress now forecast are two reasons—current world tension which has brought about much-increased emphasis on defence preparations and a general appreciation by the public of the safety and advantages of civilian air travel.

Aircraft manufacture has been undertaken in Canada in a manner never seen before and both the North American Aviation F-86E "Sabre" jet-engined fighter and the Avro-Canada CF-100 "Canuck" twin-jet long-range fighter are to be made in quantity in Canada for the Atlantic Pact Allies. The Montreal plant of Canadair Limited is to produce a total of some 800 of the F86E "Sabres." These jet fighters— the initial output of an estimated order for 400—are coming off the assembly line at a steady pace as the Canadair plant gets into full-scale production of $130,000,000 worth of what is no doubt the world's fastest military aircraft in squadron service.

Canadair received a contract for 100 "Sabres" in August, 1949, with the stipulation that the first fighter be off the line in 12 months time. This order was worth $30,000,000, and the first fighter, a F-86A, was produced last August on schedule. This brought new orders to the extent of $100,000,000, a total of 400 planes.

While the production of basic parts has gone ahead, the final modifications to the original fighter, made as a result of United States Air Force combat experience, have been completed to allow full scale production of an essentially different aircraft—the F-86E.

The Canadair plant, which owns 110 acres of land and has 1,700,000 square feet of factory space, is expanding rapidly to meet any need. Considerable space is available where the plant formerly produced the "Canadair-Four" transport for British Overseas Airways, Trans Canada Air Lines and Canadian Pacific Airlines. Five thousand men are employed on the jet production. The power plant of the F-86E is the General Electric J-47. When the Canadian-designed Avro "Orenda" engine, developed by A.V. Roe (Canada) Ltd., in Toronto, is brought into production it will replace the American engine.

To speed jet production in Canada 45-year-old *Joe Russell*, formerly with Canadian and American aircraft companies, has been appointed to head a new aircraft production division in the Canadian Trade Department. It is believed that increased production of the CF-100, the all-weather fighter made in Toronto by Avro-Canada will be called for. The CF-100 uses the "Orenda" engine also.

Aircraft orders account for $330,000,000 of Canada's defence allocation in the current year. That figure may be boosted.

In the field of civil transport aircraft, Canada's first jet airliner continued to be in the news during 1950. Among numerous record-breaking flights during the year, the Avro-Canada "Jetliner" flew 1,570 miles from Toronto to Chicago and New York, with stops in the latter two points, in four hours and 22 minutes. The plane reached a ground speed of 520 miles an hour and averaged 360 miles an hour for the over-all flight. On the Chicago-New York flight it set two records for transports in the United States: an altitude record of 36,000 feet and a rate-of-climb performance by climbing to 30,000 in 22½ minutes. The "Jetliner" has flown as high as 39,000 feet in Canada.

SERVICE AVIATION

Meantime the Royal Canadian Air Force has been quietly stepping up recruiting and has circularized all former officers regarding their willingness to rejoin the service. A few hundred men have been taken on.

Simultaneously, the tremendous wartime success of the British Commonwealth Air Training Plan is not being disregarded. Already small groups of R.A.F. personnel have arrived in Canada to take their training here. More will follow during the year and some establishments which have not been in use since the end of the Second World War have been re-activated.

Montreal, capital of international civil aviation, as seen from Mount Royal. ICAO and IATA headquarters are in the tall white building at right, middle distance.

Pretoria, capital of the Union of South Africa: the Union Buildings, i.e., the seat of Government. Parliament meets in Cape Town.

AIR TRANSPORTATION

On the civilian front the government-owned Trans-Canada Air Lines flew more passengers more miles than ever before and Canadian Pacific Airlines during 1950 established its Canada-Australia run via the Orient. In addition, C.P.A. has established scheduled flights through the Canadian northwest which formerly were served by 10 independent operators on a catch-as-catch-can basis.

C.P.A. now is operating four trips a week out of Vancouver on the airlift service, carrying United Nations personnel to Tokyo. The C.P.A. aircraft work in conjunction with a Canadian Air Force transport squadron assigned to trans-Pacific airlift work in the Korea fighting.

On the T.C.A. side new expansion took place on April 1st with inauguration of flights from Montreal to Paris and return as a result of the signing of a bi-lateral air agreement by the Canadian and French Governments.

South Africa

AIR DEFENCE

Pretoria, April: The "Black Continent" has not escaped the world fever of preparing for any emergency that a cold or a hot war may bring, a fact which is reflected in the discussions of the Union Parliament in February. From the beginning both Prime Minister Dr. Malan and Defence Minister Erasmus had to answer questions and give assurances regarding the state of military preparedness of South Africa, its participation in the fight against Communism and the possibility of coming to an understanding with other African territories about a common defence front from "Cape to Cairo." The danger that Africa with its vast deposits of strategic minerals, from uranium to manganese ore, may become a sphere of attraction for an aggressor, together with the realization of what modern air power can achieve, has removed the feeling of safety that South Africa still had in the last war. Never in peacetime, said Erasmus, had the Union's land, sea and air forces been so well equipped as at present, and new equipment was continually being purchased.

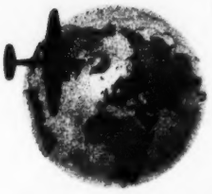
The South African Air Force had been modernized, the Minister said, and its hitting power greatly increased. Erasmus did not go into details, but it is well-known that a new flight of de Havilland "Vampires" will arrive in Cape Town in March or April for the S.A.A.F. The Union's vast coastline, from Walvis Bay in Southwest Africa around the Cape of Good Hope to the Indian Ocean north of Durban, makes it necessary to organize an effective defence for important ports as well as for the protection of convoys rounding the Cape, the "half-way house" between West and East. To replace the obsolete "Venturas" of coastal S.A.A.F. squadrons with the most modern equipment, the S.A.A.F. hopes to acquire Lockheed P2V "Neptune" patrol bombers. Negotiations for this purchase and for the release of the aircraft by Washington are in progress. South Africa's participation in the Korean campaign, where the S.A.A.F. No. 2 Squadron is in action, will provide the country with a nucleus of battle-trained airmen.

CIVIL AVIATION

While these discussions went on in the House of Assembly, Cape Town was also the scene of important negotiations on questions of civil aviation. Whitney Straight, Deputy Chairman of B.O.A.C., met the General Manager of the South African Railways, Mr. Heckrooth, to prepare for the time when the de Havilland "Comet" will make its appearance in Africa within the framework of the South African Airways-B.O.A.C. "Springbok" service partnership. This will give the British partner the chance of recovering ground lost by the Handley Page "Hermes" to the extremely popular and successful S.A.A. Lockheed "Constellations," which at present provide the best-patronized air service between Johannesburg and London.

For the current year prospects for the State-Controlled airline are promising, not only because of the general boom in air bookings to Europe already noticeable this year but also in connection with other air traffic negotiations held recently at Cape Town. A delegation from Israel arrived to finalize a bilateral air agreement between this country and South Africa.

Another matter still in abeyance are the recent negotiations in Cape Town between a K.L.M. delegation and Secretary for Transport Jack Gibson. The Dutch asked for the maintenance of their twice-weekly South African service, plus a third flight during the April-November peak period, as well as for a number of cargo flights. In turn, they were presented with a categorical South African demand to restrict their activity to five flights per month between Amsterdam and Johannesburg and to stop taking passengers to and from Rome. The date of enforcement of these restrictions has been given as May 1st. The K.L.M. delegation refused to accept the South African terms because they regard them as a violation of the air agreement between the Netherlands and the Union. It remains to be seen if an agreement can be reached—perhaps on a higher level— or if South Africa will give notice of termination of the bilateral agreement. A year's notice must be given and in the meantime the status quo would be maintained.



What's in the Air ?*

AIR BASES FROM POLE TO POLE

In 1947 the Swedish government ordered ground radar equipment for the Swedish Air Force from the U.S.A. A large order that was very welcome to American industry, not over-busy at that time. On 11th March, 1951, the Swedish Minister of Defence, Allan Vougt, announced that the U.S. authorities had refused an export licence for this radar equipment, already paid for, and Stockholm circles have stated that this refusal is remarkably similar to the order under which the U.S.A. retained in America shortly before the outbreak of World War II 300 military aircraft originally destined for Sweden.

Does this export prohibition really indicate an imminent crisis? We do not believe so.

For one thing the U.S.A. are probably not too anxious to have their latest radar equipment set up in the immediate vicinity of the U.S.S.R. It is also obvious that some regard must be had for the feelings of the American tax-payer and consumer, who is encountering difficulty in purchasing raw materials for civilian consumption and would find it difficult to understand that raw materials which are withheld from him should be supplied, in the form of radar equipment, to a country which has remained outside the Atlantic Pact.

Finally, and most important, the U.S.A. needs all its available radar equipment itself, since it is at the moment negotiating with Canada for the establishment of a common air defence system. In view of the tremendous area to be protected there can be no question of really complete radar cover. The two countries will have to be content for the time being with protecting their most vital economic centres. The areas envisaged are:—in Canada, the Montreal-Toronto-Ottawa region; in the U.S.A., the industrial regions of the East and Middle West: New York, Pittsburgh, Detroit, Cleveland, Chicago, etc. On March 27th the formation of a *U.S.-Canadian Civil Defence Commission* was announced. This is to take over the evaluation of reports, set up training centres for civil defence and co-ordinate the civil defence organizations of the two countries.

These defence measures are being accompanied by an acceleration in the organization of the network of American bases throughout the world, the main emphasis having been placed in recent weeks on strengthening the Arctic air bases.

The U.S. Army and the U.S.A.F. are to spend $1,500,000,000 on a building programme during the current fiscal year. The lion's share, viz. $1,191,000,000, is to fall to the Air Force. Of this, $14,004,900 is reserved for Eielson Air Force Base (Alaska) and $18,401,900 for Ladd (Alaska). In a radio interview on March 18th Colonel Bernt Balchen, the American Arctic expert, stated that any offensive operations by the U.S.A.F. would probably be largely carried out over Arctic or sub-Arctic regions. Intensive practice flights had proved that polar flights in large formation were no longer a problem for present-day American aircraft, since the temperatures met with over the Pole were no lower and the general weather conditions no worse than those under which normal service operations by certain U.S.A.F. units were already being carried out both at home and abroad.

American-Danish negotiations begun on March 27th in Copenhagen and held in secret, on the *defence of Greenland within the framework of the North Atlantic Treaty* form a continuation of the U.S.-Danish agreement signed in April, 1941, ceding air bases in Greenland to the U.S.A.F. It is stated in the Danish capital that Denmark would participate in the tactical defence of the island with relatively small Naval and land forces, whereas the strategic tasks would continue to be performed by the U.S.A.

At the same time an Anglo-U.S.-Chilean Naval conference was taking place in Valparaiso to discuss the strengthening of the strategically important Straits of Magellan at the Southern tip of South America.

In addition the modernization of bases on the continent of American is continuing. The U.S.A. and Canada are to spend $200,000,000 jointly on installations in Newfoundland. The U.S.A.F. has also received funds for the long-planned expansion of Edwards Air Force Base, near Muroc (California). The dried up salt lake in the Mojave desert, on which Muroc lies, offers a "natural" landing runway 8 miles long and such outstanding conditions for test flying that all operations from the traditional American training and test base at Wright Field are to be transferred to Edwards.

As regards Europe, the French Government handed over the La Martinerie Air Force depôt, near Châteauroux (Inde) (a former factory of the S.N.C.A. du Centre aircraft works) to the U.S.A.F., which is to set up a large Air Force stores depôt at Châteauroux (2000 to 3000 technical personnel of the U.S.A.F. and 7000 French engineers, mechanics and other staff).

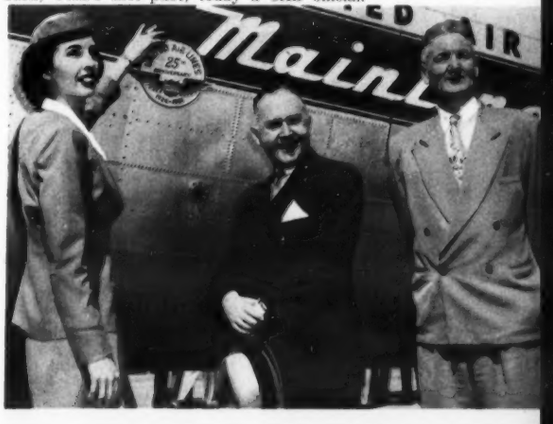
AIRCRAFT INSTEAD OF AUTOMOBILES

If we review the recently-published financial reports of the American aircraft concerns, it is easy to see why the market for commercial transports has become a "seller's market" in which all the wishes and require-

a) *Delos W. Rentzel* (left)—who as President of the Civil Aeronautics Board took the reorganization of American civil aviation energetically in hand (programme for regulating rates, control of charter business, breaking away from the subsidy system, airlines self-supporting) —has been appointed Under-Secretary of Commerce with extensive powers over commercial aviation and merchant shipping.
b) The *Presidency of the CAB* has been taken over by Rentzel's close colleague *Donald W. Nyrop* (right), hitherto President of the Civil Aeronautics Administration, where he has been succeeded by Charles Horne, also a personal friend of Rentzel's.

Hi, helicopter! To mark the centenary of the postage stamp in Denmark the historic "cylinder mail" coach delivered a batch of mail to Rosenborg Castle where it was picked up by a mail helicopter and carried to Copenhagen-Kastrup airport.

Outside the Emperor's palace in Tokyo. Schoolboys, still dressed in military-type uniforms, are willing guides to newly arrived air force members on their way to Korea. The reward? First-class term reports for English . . .



United Air Lines celebrated its 25th birthday on 6th April, 1951. The recently published financial report (net profit 1950 : $6,429,723 compared with $2,249,405 in 1949) did much to provide a happy atmosphere. From left to right: "Miss 25th Anniversary," a UAL stewardess born on the date of the foundation of the company ; —*W. A. Patterson, President of UAL*—Leon D. Cuddeback, UAL's first pilot, today a CAB official.

* Extracts from INTERAVIA AIR LETTER, daily international news digest, in English and French. All rights reserved.

ments of the purchaser are forgotten in the hesitating question: "When can you let me have some aircraft?"

The following net profits are reported for the 1950 business year:—Boeing $10,826,588 (1949: $4,411,348) Douglas $7,214,000 (1949: $5,516,700), Consolidated Vultee $10,241,644 (1949: $3,713,156), Curtiss-Wright, $7,278,564 (1949: $2,750,361), Grumman $6,242,064 (1949:$3,191,520), Lockheed, $7,209,934 (1949: $5,481,000), United Aircraft, $13,204,128 (1949: $10,093,182).

But that is not all. If profits doubled in the past year, the backlog of orders held by the leading firms sometimes trebled or even quadrupled. For example, Boeing booked orders for a round thousand million dollars (against $300,000,000 in 1949). No wonder the company has sub-contracted 39% of the parts for its B-50 and B-47 bombers and C-97 transports to outside firms.

The same applies to Lockheed, who can no longer cope at its own plant with the mass orders from the U.S. Navy for the P2V-5 "Neptune" twin-engined patrol bomber and anti-submarine aircraft (other customers interested in this aircraft are Australia, Great Britain, Holland, Canada, New Zealand, South Africa). The following are helping at present in the production of the "Neptune": Chance-Vought—tail parts; TEMCO—wings; Rohr—engine accessories and cowlings; Kaiser-Frazer (aircraft division)——fuselage parts and landing flaps.

In addition, as during World War II, the American aircraft industry is harnessing the leading automobile manufacturers to its wagon: Pratt and Whitney, the engine division of United Aircraft has given production rights to Chrysler and Ford (10,000 Pratt and Whitney R-4360 "Wasp Major" piston engines) and is negotiating with Nash (R-2800 "Double Wasp") and Hotpoint Inc. (Pratt and Whitney J-48 jets). Packard, Studebaker and Willys-Overland Motors, the builders of the world-famous jeep, are taking part in the production of General Electric J-47 jets. The Hudson Motor Car Co. is preparing the production under licence of the Wright R-3350 piston engine, and the Rheem Manufacturing Co. is to make fuselage noses for the Lockheed T-33 fighter trainer and the Lockheed F-94 all-weather fighter.

It goes without saying that General Motors Corporation's non-aviation divisions (Chevrolet, Frigidaire, Buick) are also working on the parent firm's aircraft engine and propeller programme.

It looks as if the unfortunate American will be able to buy fewer and fewer automobiles and refrigerators.

The "*Helicoplane*," a design of a convertoplane worked out by the French engineer *H. F. Giroz*. Also to be driven by gas turbines.

"*CONVERTOPLANES*"

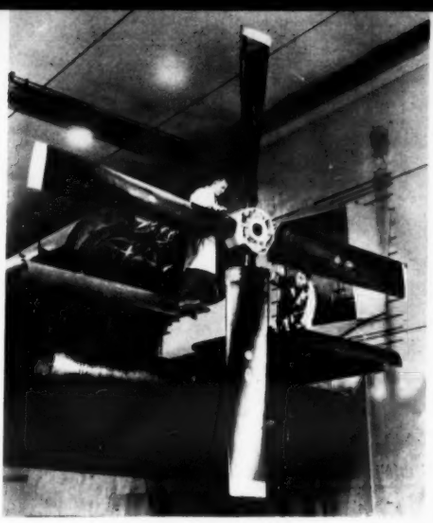
Scarcely has the helicopter achieved recognition than it is being "re-modelled" by certain indefatigable designers. The new aircraft, the "Convertoplane" is to have the qualities of the helicopter (vertical take-off and landing) with the high horizontal speed of the fixed-wing aircraft. After a vertical take-off the plane is converted from a helicopter into a fixed-wing aircraft (for example by tipping forward the rotor carriers so that the rotors act as propellers and the carriers become stub wings). Landing (hey presto) takes place again as a helicopter or autogyro.

The Finnish *Valmet* "*Vihuri*" fighter trainer-span 33 ft. 1 in. (10.4 m), wing area 204 sq.ft. (19 m²), maximum speed 274 m.p.h. (440 km/h), service ceiling 28,000 ft. (8500 m).

The Gyrodine Co. of America, Inc., Convertawings Inc., and the Convertoplane Corp. are all working on plans for convertoplanes in the U.S.A. and first details have recently been released of a design worked out by J. Oliver Black of Detroit and Professor Joseph Rutkowski of the University of Wayne.

As was to be expected, the military authorities are showing great interest in this work, which is still in its early stages. The U.S.A.F. has organized a design contest for convertoplanes and is at present checking the plans sent in by 17 factories and research groups. Although adequate funds are available for development work, it is thought in authoritative circles that prototypes of a convertoplane will not be ready for testing for about three years.

There are sponsors for this class of aircraft not only in the U.S.A., but also in Britain and in France, where preliminary studies are being made, though on a smaller scale.



For heavyweights only . . . This Hamilton Standard propeller measures 19 ft. in diameter and is being tested by Air Material Command at Wright-Patterson Air Force Base. This propeller was developed for piston-engines and turbines of over 5000 h.p.

FOR FINLAND'S FLYING PUPILS

Valmet (Valtion Metallitehtaat, Lentokonetehtaat), the aircraft construction section of the Finnish State Metal Works at Tampere, ceased constructing aircraft in 1945, after trying out the "Pyörre-Myrsky" fighter prototype with a 1475 h.p. Daimler Benz DB 605 engine. Before and during World War II the firm produced several military types of its own design, such as the "Tuisku" and "Viima" biplane trainers, "Pyry" two-seater fighter trainer monoplane and "Myrsky" and "Pyörre-Myrsky" single-seater fighters. In addition Bristol "Blenheim" bombers were built under licence.—After suspending aircraft production the firm made railway trucks for Russia and was re-christened "State Metal Works."

Four years later, however, aircraft production started up again and today the prototype of the Valmet "Vihuri" fighter is undergoing flight tests. The "Vihuri" is a two-seater all-metal low-wing monoplane which recalls the British Boulton Paul "Balliol" trainer and the North American T-28, Engine: Bristol "Mercury VIII" of 840 h.p. driving a de Havilland three-bladed constant pitch propeller.

Valmet is also working on the "Tuuli" trainer and sports aircraft. Originally developed as a two-seater low-wing monoplane, this type was later converted into a four-seater high-wing monoplane. This is to give the "Tuuli" greater flexibility in military liaison duties and as sports and touring aircraft.

JET TRANSPORTS—IN ITALY

In Britain the "Comet" has been flight tested, Canada is trying out the "Jetliner" and the French have recently started tests on the "Nene-Bretagne," a version of the SO 30 "Bretagne" fitted with two "Nene" jet engines. Now Italy has entered the scene. The Società Aeroplani Idrovolanti SIAI-Marchetti announces that it has started development of a "Chimera II" transport aircraft which is to be fitted with four jet engines. It is said to be a swept-wing model. Two of the engines are to be mounted in the wing roots and two at the wing tips. A good deal of energy appears to be going into the work and it has even been stated that the "Chimera II" will prove a worthy rival to the "Comet."

"*Comets*" *in formation*. The two aircraft in the background are owned by the British Ministry of Supply, the one nearest the camera was built for British Overseas Airways Corporation, which has ordered 14 "Comets."

Flight Planning and Direct Operating Costs

by ARMIN BALTENSWEILER, Engineering Department, Swissair, Zurich

In the struggle to make air transport pay one essential is to keep operating costs as low as possible consistent with the safety and comfort of the passenger. Efficient flight planning, i.e. the interpretation of engine power, altitude and wind force plays an important part here. In this article it is proposed to investigate the influence of these factors on direct operating costs.

For the time being the great majority of scheduled long-distance services, particularly across the North Atlantic, will continue to be operated by aircraft of traditional design. Consequently it is not proposed to discuss propeller turbines and jet engines here but to limit investigation to present-day operating problems.

Flying equipment

Because of the rapid technical advances of recent years and the increasing stringency of safety requirements, only a few piston-engined aircraft types have been found suitable for international traffic. The structural principles of these aircraft have become so nearly standardized that our investigations can be based on a hypothetical four-engined piston-engined aircraft, which in dimensions, weights and performance corresponds approximately to a present-day long-range aircraft :—

Max. take-off weight	110,000 lbs (50 tonnes)
Max. landing-weight	92,500 lbs (42 tonnes)
Max. dry weight	86,000 lbs (39 tonnes)
Wing area	1,480 sq. ft. (140 m²)
Take-off power per engine	2,700 h.p.
Rated power per engine	2,300 h.p. (supercharger in low gear)
Rated power per engine	2,000 h. p. (in high gear)
Max. cruising power	1,500 h.p.
Fuel capacity	5,060 Imp. gals. (35,900 lbs.) (23,000 litres = 16,300 kg)

Elements of route flying

Every flight falls into six clearly distinguishable stages (fig. 1), viz. : movement on the ground, take-off and climb, horizontal flight, descent, landing approach and landing, taxying to stopping point. In each stage there are different power and speed conditions, which are themselves influenced by atmospheric conditions such as density and wind.

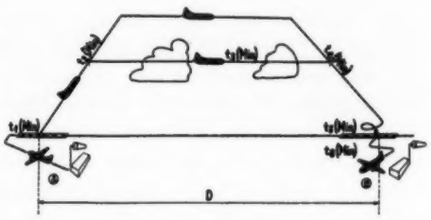


Fig. 1 : Elements of route flight.

Times (Min.) :

t_1 taxying to take-off runway
t_2 take-off and climb
t_3 cruising flight
t_4 descending
t_5 landing approach and landing
t_6 taxying to unloading area.

Distance : D (Km)

Block speed : $V_B = \frac{60\ D}{\Sigma\ (t)}$ (km/h)

However, both passengers and air transport company are far less interested in actual operating conditions than in the time elapsing between entering and leaving the aircraft. This time is known as " *block time* ". Similarly we get the term " *block speed* ", the result of dividing distance by block time. Since the ratio of the time of climb to total journey time becomes smaller and smaller as distance increases, the block speed for a given cruising altitude and engine power is a function of the distance (cf. fig. 4). If engine power and altitude are fixed for the various stages of the flight, and atmospheric conditions are known, the consumption of fuel (and oil) [1] can be calculated. Safety regulations require a fuel reserve to be carried, sufficient to enable the aircraft to remain in the air an extra 1½ to 3 hours after reaching its aerodrome of destination, either to wait for permission to land or to fly on to another aerodrome in the event of bad weather. When the weight of the fuel required has been determined it is possible to fix the payload in relation to the distance (fig. 2).

Before going further into these questions it will be advisable to give a definition of the terms used :—

Term	*Definition*
Weight empty	Weight of airframe, engine and fixed equipment, unusable fuel supply, undrainable oil, total quantity of engine coolant and total quantity of hydraulic fluid.
Useful load	Crew and their baggage, fuel and oil, payload.
Gross weight	Total of weight empty and useful load (varies between take-off weight and landing weight).
Operational weight empty	Take-off weight minus fuel and payload [1].
Zero fuel weight	Weight limit without fuel.

[1] To simplify matters it is usual for the whole of the oil in small aircraft to be included in the operational weight empty. In long-distance aircraft oil consumption is given for example as 2% by weight of fuel consumption, it being laid down that on take-off the total quantity of oil must be at least 4% by weight of the fuel carried.

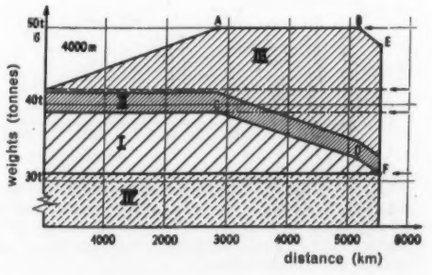


Fig. 2 : Weight diagram for a long-distance aircraft with 50 tonnes max. take-off weight. Flight with zero wind at altitude of 4000 m., with constant engine output (4 × 1500 h.p.).

Max. take-off weight	Weight on take-off which for safety reasons (failure of one engine) may not be exceeded.
Max. landing weight	Gross weight which may not be exceeded for landing.

For short distances, the size of the payload is determined by the zero fuel weight, since no commercial load may be carried in excess of this weight. Another fixed quantity is the fuel reserve. The fuel required for any desired distance is given in the diagram as a variable ordinate. It follows that the take-off weight of the aircraft for short distances increases steadily until it reaches the permissible maximum at point A. The angle of inclination of this straight line is a measure of the so-called " specific range " (in km/kg). A steep rise means that a relatively large quantity of fuel is used per unit distance. As take-off weight cannot be increased beyond point A the fuel required for longer flight distances can only be carried at the expense of payload. At point C payload therefore begins to decrease until at point D all fuel is used up and the maximum flight distance is reached.

If the first essential is to get the longest possible range, the take-off weight can be slightly reduced, at the expense of payload, with fuel tanks full. This reduces the mean gross weight, which in turn gives an improved specific and absolute range. This possibility is indicated in the diagram by the lines B-E and D-F, though it should be noted that this system is of no value in commercial long-range operations.

Engine output

The output range of a piston engine is normally understood to mean the whole scale between idling and take-off output, though it must be remembered that there are limitations on the extent to which the whole range can be used. For example, take-off output is generally limited, for safety reasons, to a maximum of two minutes. And although theoretically the engines can run for an unlimited time at maximum continuous output, it has been found that this reduces their life and reliability to an unwarrantable degree. In practice therefore cruising outputs of 30-70% of the rated output and climbing outputs of approximately 80% of the rated output have been introduced.

The upper limits of engine output have been fixed by regulations and by the recommendations of the makers, but it is the output required by the aircraft to maintain stable flight—depending on weight and altitude—which sets the lower limit. These laws, laid down simply by the mechanics of flight, can be illustrated in an output-speed diagram. So that fuel consumption figures, which are so important in calculating useful load and range, can be obtained, it has become the custom to represent the " specific range " as a function of the true speed with output as a parameter. The " specific range " is taken to mean the number of route kilometres covered per kilogram of fuel. Fig. 3 shows the Specific Range for various gross weights and an altitude of 6000 m.

With the aid of this diagram the usual variations of output occurring in route flying can be discussed in full. These are as follows :—

— flight with constant output
— flight at constant speed
— flight to obtain maximum range
— flight at constant angle of incidence.

Each of the above procedures has its advantages and its disadvantages, and only a detailed investigation can show in what cases a selected output will be of operational advantage.

If the case of *constant output* (1500 h.p. per engine) is examined it will be seen that the aircraft's true speed increases as gross weight is reduced. As is shown by fig. 4, this fact finds expression in a high block speed, whilst the maximum distance and consequently the payload (fig. 5) remain relatively small, owing to the modest specific ranges. Flight at constant output is simple from the operating point of view, as all the crew has to do after the end of the climb is to set a selected constant output. This must of course make allowance for the progressive increase in speed in long-distance navigation.

Flight at *constant speed* on the other hand has advantages from the navigation point of view, though it means, as will be seen in fig. 3, that output must be constantly adjusted. In practice this is of course done step by step. A mean output is set for a given weight range, then after a time, when

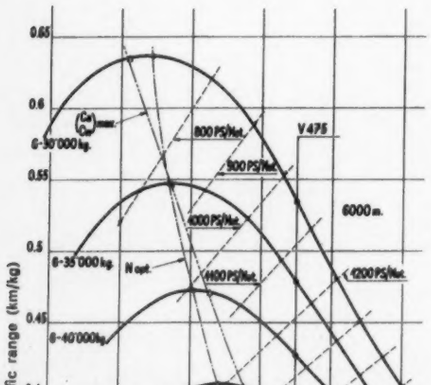


Fig. 3 : Specific range (in km/kg) for an altitude of 6000 m. plotted against true speed (in km/h) and gross weight (in kg).

N_{opt} : maximum range
V_{475} : flight at constant speed of 475 km/h (TAS)
$\frac{C_x}{C_y}$ max. : flight at optimum lift/drag ratio

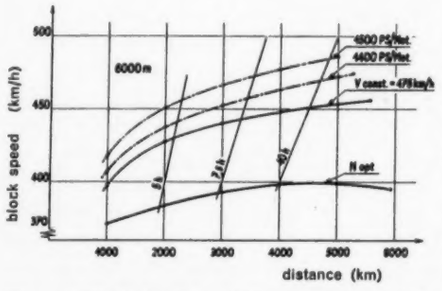


Fig. 4 : Flight speed for 6000 m. altitude plotted against flight distance, for constant engine output (1500 h.p. and 1400 h.p. per engine), constant speed (475 km/h TAS) and optimum output (N_{opt}) to obtain maximum range.

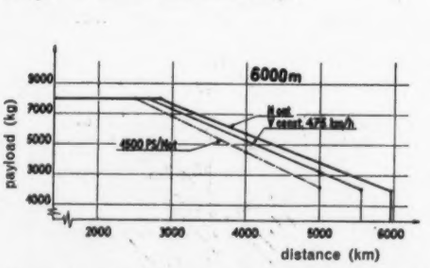


Fig. 5 : Payload for 6000 m. altitude plotted against distance, for constant engine output (1500 h.p. per engine), constant speed (475 km/h TAS) and optimum output (N_{opt}) to obtain maximum range.

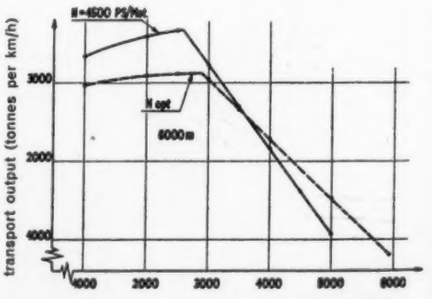


Fig. 6 : Transport output for 6000 m. altitude plotted against distance, for constant engine output (1500 h.p. per engine) and optimum output (N_{opt}) to obtain maximum range.

the gross weight has been reduced by the consumption of a certain quantity of fuel, the next lower mean output is set. As the speed remains constant, the flight speed is lower than in the former case.

For very long flights it is sometimes important to get the *maximum possible range*. In fig. 3 this situation is shown by the line joining the maxima of the continuous curves (weight curves). Here too the output must be adapted to the progressively decreasing gross weight, i.e. it must be reduced by stages. The true speed thus becomes progressively lower, whilst the specific range considerably increases. The block speeds are consequently also low, but payload is at a maximum. In practice a slightly higher speed is chosen, for reasons of stability. It has been agreed that output for each weight category should be so fixed that speed is 10-15 % higher than that of the maximum specific range.

A special instance of flight with *constant angle of incidence* is the case of the optimum lift/drag ratio. As fig. 3 shows, the line representing this case is fairly close to the output curve more frequently used in practice to obtain maximum range. Flight at optimum lift/drag ratio is therefore equal to the latter procedure as regards block speed and payload. A common feature of both cases is that neither output nor speed remain constant during the flight, which complicates the work of the crew.[2]

The results of the first three systems are shown in figs. 4 and 5 in the form of block speed and payload diagrams.

As block speeds and useful loads are characteristic values for each commercial aircraft, it is obvious they should be combined in the form of the *transport output*. This gives the work done per hour in tonnes-km or, with suitable conversion to a year's flying time, the corresponding work per flying year. In fig. 6 the transport outputs on the one hand for a constant engine output (1500 h.p. per engine), and on the other for the long-distance setting (maximum range) are shown side by side. The diagram shows that it is only for short flight distances that a higher cruising output also gives higher transport outputs, whereas for very long distances the reverse is the case. If the transport work is related to the amount of fuel consumed, an idea is obtained of the utilization of the fuel, in the form of a profitability figure (fig. 7). As is to be expected, this figure, for all flight distances, is highest

[2] If the equipment for constant recording of the angle of incidence now being developed for jet transports comes into use, flight with constant angle of incidence will probably become more important even in the case of piston-engined aircraft.

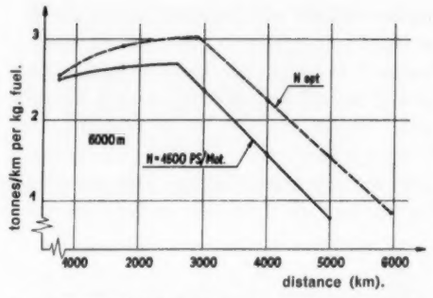


Fig. 7 : Profitability figure for 6000 m. altitude plotted against distance, for constant engine output (1500 h.p. per engine) and optimum output (N_{opt}) to obtain maximum range.

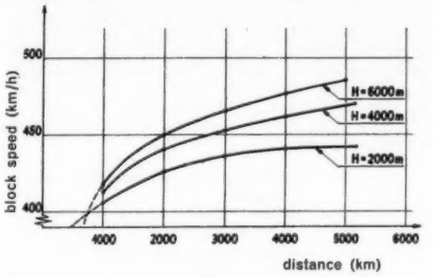


Fig. 8 : Block speed plotted against distance for three altitudes, for constant engine output (1500 h.p. per engine) and zero wind.

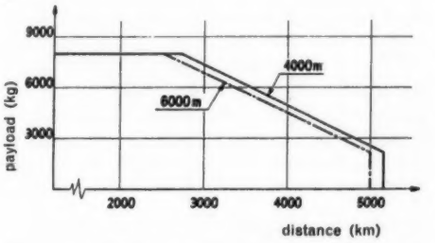


Fig. 9 : Payload plotted against distance for two altitudes, for constant engine output (1500 h.p. per engine) and zero wind.

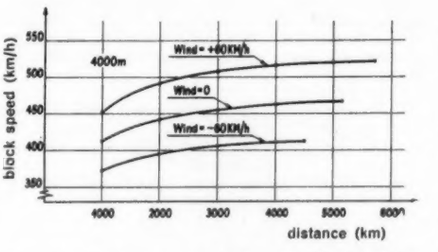


Fig. 10 : Influence of wind on block speed, for constant engine output (1500 h.p. per engine) at 4000 m. altitude.

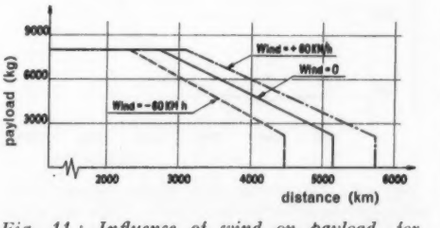


Fig. 11 : Influence of wind on payload, for constant engine output (1500 h.p. per engine) at 4000 m. altitude.

when the engine output is selected so as to give the greatest possible useful load and range.

As will be seen later, it is not essential that an increase in fuel consumption should mean increased costs (cf. figs. 12 and 13). As, in addition, the long-distance engine output results in a reduction in transport output for smaller stages, it must be concluded that the profitability figure does not always give a true picture. On the other hand the transport output does enable a realistic estimate of the transport potential to be made as a function of the flight distance.

Altitude and wind effect

It is not possible here to examine all the possible variations. We shall therefore restrict ourselves to deducing the effect of altitude at zero wind on the parameters for maximum cruising output (1500 h.p. per engine). At constant engine output the block speed increases with increasing height, owing to the reduction in density (fig. 8). For distances of under 1000 km, conditions are the reverse however, as here the long time of climb to great heights reduces the block speed and thus cancels out the gain in time. For short distances and a given engine output there is therefore always a definite optimum altitude.

On the other hand, at high altitudes the payload decreases, a fact conditioned by the characteristics of piston engines. To get a certain engine output a higher r.p.m. is needed here, which entails a correspondingly higher specific fuel consumption (fig. 9). This applies primarily to *high* cruising outputs. The differences in our example are relatively small, but might in extreme cases (maximum payload and range) become of paramount importance. In practice altitude will as a rule be determined by wind and weather conditions.

Now that the pressure cabin has become standard in all modern commercial aircraft, which can now fly at any altitude up to 6000 m. without detriment to passenger comfort, the pilot will normally pass through the zones of increased turbulence. To reduce the effect of head winds or to take advantage of following winds he must also take account of meteorological conditions. As wind force increases with altitude the pilot will always try to fly lower when there is a head wind. Conversely a strong following wind will be of particular assistance at high altitudes.

Figs. 10 and 11 show block speed and payload for following and head wind for a wind force of 60 km/h at 4000 m. (by no means

rare over the North Atlantic). It is obvious how much stronger is the influence of wind conditions on long-distance operations than of output and altitude. This is the reason for the use of " wind " or " meteorological " navigation on long stages. Under this system a somewhat longer route is followed so that advantage can be taken of better wind conditions and flying time thus reduced.

Direct operating costs

A distinction must always be made, when considering expenditure, between costs which are directly concerned with the flight and general costs which are distributed among the company's various routes according to a fixed formula, i.e. between direct and indirect operating costs.

Direct operating costs are as follows :—

— depreciation of airframe and engines
— insurance
— upkeep and overhaul costs
— crew
— cost of fuel and oil

Depreciation and insurance are always *annual expenses*, which must be paid regardless of the frequency with which the aircraft are used. The cost per hour of flight therefore decreases as the number of flying hours increases. Upkeep and overhaul costs can be expressed as " *fixed hourly costs* " and depend primarily on the size and structure of the aircraft. The upkeep costs for the engines, however, depend on the output selected, so that the increase in speed obtained by higher output is offset to a certain extent by higher maintenance costs. Costs of crew (pay and expenses) will not be discussed here, since these are calculated differently by different companies. The specific costs of fuel and oil depend on engine output, wind force and altitude, and must therefore be described as " *variable hourly costs* ".

When the economic qualities of several different aircraft types are being considered only the direct operating costs are normally considered in detail. The same will be the case when the economic advantages of various methods of operation are compared.

All direct costs can be grouped together for a fixed distance and a specific operational system. Normally the specific value per route kilometre is used for purposes of comparison, and is obtained by dividing the direct costs by the route length. If then the payload carried over a certain section of the route is also taken into consideration, the costs per tonne/km can be worked out.

Fig. 12 shows how costs per kilometre are affected by the choice of engine output. Higher outputs and resultant higher speeds produce a reduction in costs per kilometre. Unless it is essential to insist on full utilization of useful load potential or on maximum range, it will therefore be of advantage to select a higher engine output. When these costs are also related to the unit weight of the payload, the reduction in payload over

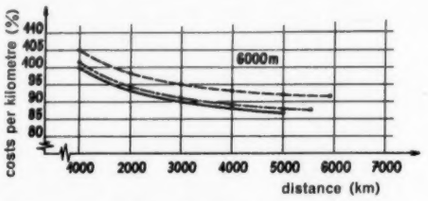


Fig. 12 : Cost per kilometre for 6000 m. altitude (with zero wind) plotted against distance and engine output. Costs are given as percentage of the costs per kilometre obtained for a distance of 1000 km at a cruising output of 1500 h.p. per engine.

——— : constant engine output (1500 h.p. per engine)
—·—·— : constant speed (mean output 1300 h.p. per engine)
– – – – : optimum range (mean output 1100 h.p. per engine)

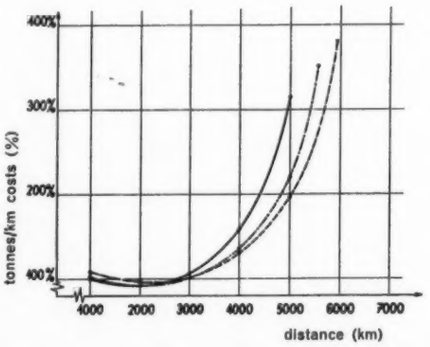


Fig. 13 : Tonnes/km. costs for 6000 m. altitude (with zero wind) plotted against distance and engine output. Costs are given as a percentage of the tonnes/km costs obtained for a distance of 1000 km for a cruising output of 1500 h.p. per engine.

——— : constant engine output (1500 h.p. per engine)
—·—·— : constant speed (mean output 1300 h.p. per engine)
– – – – : optimum range (mean output 1100 h.p. per engine)

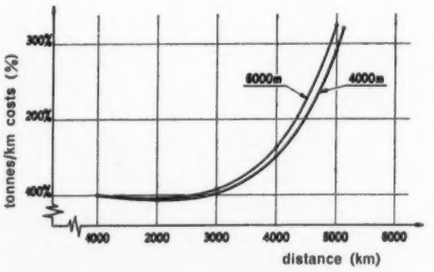


Fig. 14 : Tonnes/km costs plotted against distance for two altitudes (no wind). Costs are given as a percentage of the tonnes/km costs obtained for a distance of 1000 km. and an altitude of 4000 m.

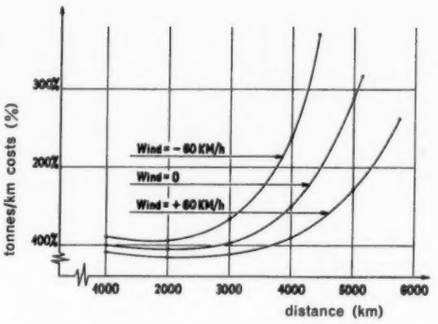


Fig. 15 : Tonnes/km costs (for 4000 m. altitude and 1500 h.p. per engine) plotted against distance and wind force. Costs are given as percentages of the tonnes/km costs obtained for a distance of 1000 km and no wind.

long distances as a result of the higher fuel consumption at higher engine output becomes noticeable (fig. 13). For short distances tonnes/km costs are the lowest at maximum cruising output. As the maximum payload can be carried over long distances only if the long-distance output is used, the curves of the operating costs intersect (in our example at approx. 2500 km). It is seen that the engine output for maximum range is most economical over long distances.

The effect of air density on tonnes/km costs is seen in fig. 14. The difference in costs is not very great for altitudes of 4000 m. and 6000 m. For greater distances (and no wind) costs are greater at altitude, because of the reduction in payload (cf. fig. 9).

However, fig. 15 demonstrates that density has a much less important effect on operating costs than wind. A powerful head wind produces a considerable increase in transport costs, particularly on long-distance flights, and a following wind of similar force a decrease, though relatively smaller. As a reduction in altitude usually means a reduction in wind force, the tonnes/km cost will usually be more favourable at lower altitudes when there is a head wind. An increase in density and a reduction in wind effect also reduce operating costs. At high altitude, with following wind, the conditions are reversed ; costs are increased by only an insignificant amount because of the reduced density : a relatively small increase in following wind suffices to counteract this effect, as increasing wind force reduces the tonnes/km cost.

*

As has been shown, block speed and payload and consequently operating costs can be considerably affected by the method of flight. A detailed study of the operative factors for every aircraft type and efficient interpretation of its results will therefore pay dividends.

«CONVAIR-LINER 340»

A new transport aircraft for medium stages

Consolidated Vultee Aircraft Corporation, which was formed in 1943 through the merger of Consolidated Aircraft Corp. and Vultee Aircraft Inc., is known not only for its heavy bombers and naval aircraft but also for its commercial transports. Even before the end of the war plans had been drawn up for an economic, twin-engined aircraft for 30 passengers (Convair 110). This developed into the " Convair-Liner 240 ", the prototype of which made its first flight in March, 1947, and was certificated for commercial operation in November of the same year. Today it is almost impossible to imagine world air services without this aircraft.

Consolidated Vultee have, naturally enough, continued the development of the " Convair-Liner " still further. Its possible uses have been extended, improvements in design have several times enabled increases to be made in gross weight, and a trainer version known as the T-29 [1] has been produced for the USAF. In November, 1950, an improved version of the " Convair-Liner ", known as the " Convair 240A ", with a gross weight of 43,575 lbs, was announced. A " Turbo-Liner " experimentally fitted with two Allison T-38 propeller-turbines is being tried out at the moment. All these different versions have led up to the announcement, on the 20th February, 1951, of the first details of a new type, to be known as the " Convair-Liner 340 ".

Even the most superficial examination shows that the new " Convair 340 " differs from its predecessors in its principal dimensions, its power plant, and in some of its equipment.

First and foremost the 340 version has a considerably greater span (105 ft. 8 in. as compared with 91 ft. 9 in.). The wing area has been correspondingly increased (920 sq. ft. instead of 817 sq. ft.) and the aspect ratio raised from 10 to 12. The dihedral is also greater, namely 6°30′ compared with 4°50′ in the earlier versions. The increase in wing area permits of the installation of fuel tanks with a capacity of 1700 U.S. gallons (compared with 1550 U.S. gallons).

Otherwise the Convair 340, like its predecessors, has a twin-spar metal wing with thermal de-icing equipment in the leading edge and Fowler flaps reaching as far as the ailerons. The landing flaps are more efficient and are said to give improved take-off and landing qualities.

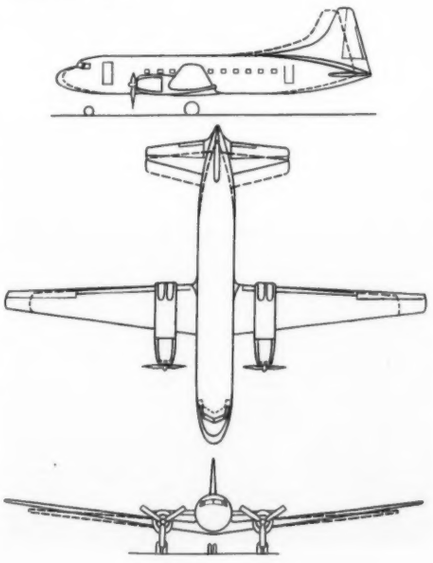
[1] Cf. " Convair T-29 " in INTERAVIA, Review of World Aviation, No. 5, 1950, pp. 252-254 and *Martin 4-0-4 and Convair-Liner*, No. 11, 1950, pp. 588-590.

What the " Convair-Liner 340 " will look like. Passenger door is on the port side of the fuselage.

The fuselage is more roomy, a point which will be of particular interest to air transport companies. Two cylindrical fuselage segments have been inserted, one fore and one aft of the wing, increasing the length of the fuselage from 74 ft. 8 in. to 79 ft. 2 in. with no change in diameter. This means that either four extra passenger seats (44 instead of 40) can be fitted or that the extra space can be used for the carriage of freight.

The tail unit is the same as that in the Convair 240. The greater total height (27 ft. 9 in. as compared with 26 ft. 11 in.) is due to the use of longer main undercarriage legs and larger wheels. The pressure system in the new model is considerably more efficient and the electrical installations have been thoroughly modernized. The hydraulic system on the other hand has remained unchanged.

Three-view drawings of the Convair 240 (dotted) and Convair 340. The differences in the main dimensions are considerable. Span 105 ft. 8 in. instead of 91 ft. 9 in.; length 79 ft. 2 in., instead of 74 ft. 8 in.; wing area 920 sq. ft. compared with 807 sq. ft.



These modifications, particularly the use of a wing of greater area, enable the gross weight of the new Convair 340 model to be increased by 10% (from 41,790 lbs to 45,000 lbs). With the same range it can carry about 2,000 lbs. more useful load at a cruising speed 8 m.p.h. higher. Thanks to the greater gross weight and higher fuel capacity the new " Convair-Liner " will doubtless have better useful load/range characteristics than the types in use today.

For the time being, the Convair 340 is still to be fitted with piston engines. Two Pratt & Whitney R-2800-CB16 " Double Wasp " 18-cylinder double radial engines with Hamilton Standard " Hydromatic " three-bladed propellers (feathering ; reversible pitch for braking during landing) are provided for. These engines (with water injection) give the same take-off power as the R-2800-CA18 engines at present used in the " Convair-Liner " (i.e. 2400 HP each) but are more efficient in cruising flight conditions at high altitudes. They thus give an increased cruising speed and greater cruising height.

Needless to say, allowance was made in the design for the possible later installation of jet engines. The strength specifications of the airframe allow for the higher stresses which would result from the use of propeller turbines, and transition from piston engines to jet engines will entail very little structural alteration.

*

In the Convair 340 Consolidated Vultee are putting on the market a machine which, while catering for possible future requirements, meets the present-day needs of the transport companies. The number of orders already placed for this new type testify to this. Within a month of the announcement of the Convair 340 substantial orders were received from United Air Lines (for 30), Braniff Airways (20), Continental Air Lines (7), and Hawaiian Airlines (4). Recently Delta Air Lines have also ordered 10 of these aircraft, and further orders have been received from the two oil companies Arabian-American Oil Co. (2) and Texas Co. (1) and from United Aircraft Corp. (1). Other orders will probably follow shortly.

GCA at Brussels-Melsbroeck Airport

GCA installations are becoming more and more common at large aerodromes and the time is past when « radar » was a great curiosity. The Ground Controlled Approach system has won pride of place through the services it has rendered over the years in many different places and conditions, and the system itself is no longer a novelty.

It would appear however that the GCA installation which the Belgian Airways Control Authority has recently put into service at Brussels—Melsbroeck airport is worthy of special mention, since it has several original features.

The first impression one obtains from an inspection of the radar installation at Melsbroeck is one of a homogeneous and harmonious whole, or in the present-day idiom, a well « integrated » whole. Too often in the past this type of installation has been more of an improvisation grafted on to an earlier organization and consequently not too well adapted to it. For example as often as not equipment was installed in a trailer. The latter, although no longer moved about, retained many of the serious disadvantages inherent in its design as a mobile vehicle. The instruments were either housed in the actual trailer, with all the consequent inconvenience of operation, or, if they could be put into the control tower, they were relegated to small, extremely inconvenient temporary quarters.

From this point of view Brussels is doubly fortunate. Firstly it is obvious that the installation has been thought of as a whole right from the beginning and that from the moment the project was started everything possible was done to make this whole not only of pleasing appearance but also practical and convenient in day-to-day operation.

The precision approach radar building (figs. 1 and 2), for example, is striking for its finish and for the convenience of its internal arrangements. A far cry from the over-crowded, frequently leaky trailers mentioned above !

Fig. 3 : Brussels-Melsbroeck control tower. The surveillance radar aerial is mounted on a metal pylon behind the glass shelter. The operations room is in the tower, directly below the glass shelter.

The aerial for the surveillance radar has been built on the top of the control tower itself (fig. 3), where very little labour was required to erect the short pylon which lifts it above the traffic controllers' glass shelter. The whole is sufficiently harmonious not to disturb the building's own particular æsthetic charm. The operators also benefit from the fact that they do not have to worry about the parallax which would exist if the aerial, and thus the centre of the P.P.I. scope, did not coincide with the position of the control tower.

The scopes have been housed in a special room, of ample dimensions and well ventilated (fig. 4). Those who have experienced the joys of long hours of work in the little black fabric hut of the average make-shift installation will understand that this small detail certainly deserves to be stressed. This room, situated in the immediate vicinity of the glass shelter, also contains the cathode ray screens of the VHF automatic direction finding equipment. The traffic controllers thus have all the information they require permanently in front of them. The fact that they can operate in an atmosphere of calm and comfort undoubtedly contributes to a not unimportant extent to the general efficiency of the system.

Adjacent rooms house other parts of the equipment (transmitter-receiver for the surveillance radar near the aerial vertical — auxiliary cabinets for the two radar systems in the radio room).

However a sound design for the installation as a whole was not enough in itself. The same concern for perfection had also to be extended to the details of the system. Close collaboration between the ultimate users of the equipment and the designers certainly helped a great deal here. And this is where Melsbroeck has benefited a second time, in having as designers the Compagnie Française Thomson-Houston of Paris, whose factories were sufficiently near at hand to permit almost permanent contact between future operators and design engineers.

The surveillance radar used at Brussels is, to our knowledge, the only radar installation of this type working on a wavelength of 3 cm. The basic reason for the choice of this frequency was the desire to obtain an aerial whose radiation diagram should be sufficiently clear of secondary lobes near the base not to produce ground echoes. These ground echoes cloud the centre of the P.P.I. scope with a mass of bright spots which

Fig. 1 : Building housing the precision approach radar aerials at Melsbroeck. The control tower, where the scopes are installed, is in the background (about 600 yds. away).

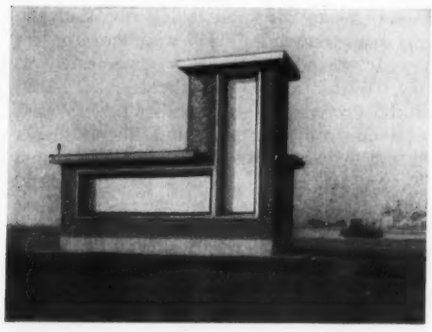
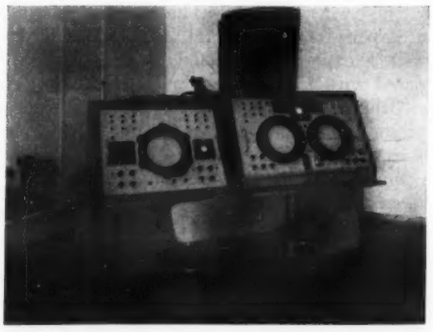


Fig. 2 : Inside the P.A.R. aerial building, showing the two-channel transmitter-receiver cabinets and the structure of the reflector of the horizontal aerial. Note in particular the length of this aerial, corresponding to a beam angle of 0.5°.

Fig. 4 : The operations room. Left : *the surveillance radar (S.R.E.) desk.* Right : *the precision approach radar (P.A.R.) desk. The whole of the installation is remote-controlled from these desks.*



make it very difficult to follow an aircraft at short range. To overcome this handicap recourse is generally had to special circuits to eliminate permanent echoes (M.T.I. circuits).[1] But this is a difficult and costly way out and is only really justifiable for high power surveillance radar installations.

Here the designer's object was rather to produce a radar installation which would most efficiently and economically fulfil the requirement of a Surveillance Radar Element as laid down by I.C.A.O.

The technical solution decided upon i.e. to cut down to the minimum the waves reflected by fixed obstacles, so as not to have to eliminate their disturbing images from the scope, was excellent, but in order to get a rotating aerial whose dimensions were not completely prohibitive it was essential to use a wavelength of no more than 3 cm.

This meant that very powerful anti-clutter circuits had to be added to the equipment to eliminate the disturbance caused by rain, etc., on these frequencies.

The final result is very satisfactory and in some respects — sharpness of images in particular — quite striking. It would seem that this equipment represents an interesting answer to the particular problem for which it was designed, that of the surveillance radar element. Nevertheless this does not alter the fact that when a surveillance radar of much greater range is required for traffic control — but then we are getting away from the problem of G.C.A. proper — high-power 10 cm. radar with M.T.I. is indispensable, though more fragile and much more costly. Brussels is also to have an installation of this type in the near future.

The precision approach radar has the characteristics now fairly generally accepted for this type of equipment. The horizontal aerial is much bigger than in older models (fig. 2), its dimensions having been increased to provide the greater precision recently required of the beam (0° 5 aperture instead of 1° 1). To our knowledge Melsbroeck is the first airport to have this type of equipment.

Various tests were made, in collaboration with the future operators, to ascertain the best way of super-imposing on the images on the radar scope the maps containing the necessary indications (line of descent, axis of runway etc.). Several systems were tried out. An ideal solution appears to have been found in a map drawn in red, without parallax, with controllable illumination ; this is easily visible against the greenish background of the echoes. An interesting point is that this equipment can have a camera attached to it which automatically and repeatedly photographs the scope during operation without hampering the operator. This system, along with the electrical recording of conversations between traffic controller and pilot, provides a valuable means of checking the work of the G.C.A. unit. Experiments are continuing and should, we feel, be followed with interest.

Finally, reference should be made to the effort that has been made in the design of this equipment to facilitate the delicate work of maintenance. All the cabinets have lines of test points on the front which enable the essential parts of the circuits to be checked with the maximum ease (fig. 5). The individual chassis can be pulled out of their racks and tipped down for ease of inspection (fig. 6), without interrupting their operation. Thus everything possible has been done for the convenience of the operator.

[1] Cf. H. V. Tanter, " Radar Instruments with Elimination of Fixed Obstacle Indication ", INTERAVIA, Review of World Aviation, Vol. V, No. 5, 1950, pp. 255-256.

Fig. 5 : Transmitter-receiver for the precision approach radar. Note the rows of test points with their labels. The whole installation can be tested rapidly by this means. The two left-hand cabinets are identical, one set being in operation, while the other acts as a reserve.

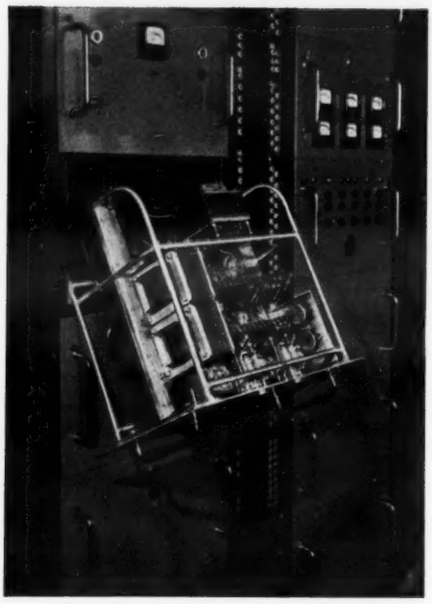


Fig. 6 : Surveillance radar (S.R.E.). Typical arrangement of a CFTH swivelling chassis. The valves are upside down underneath the base plate, the circuit elements are mounted on small plates in readily accessible positions on top of the base plate. The button controls are grouped together on one side. Cooling is by an air current, controlled on a level with the base plate.

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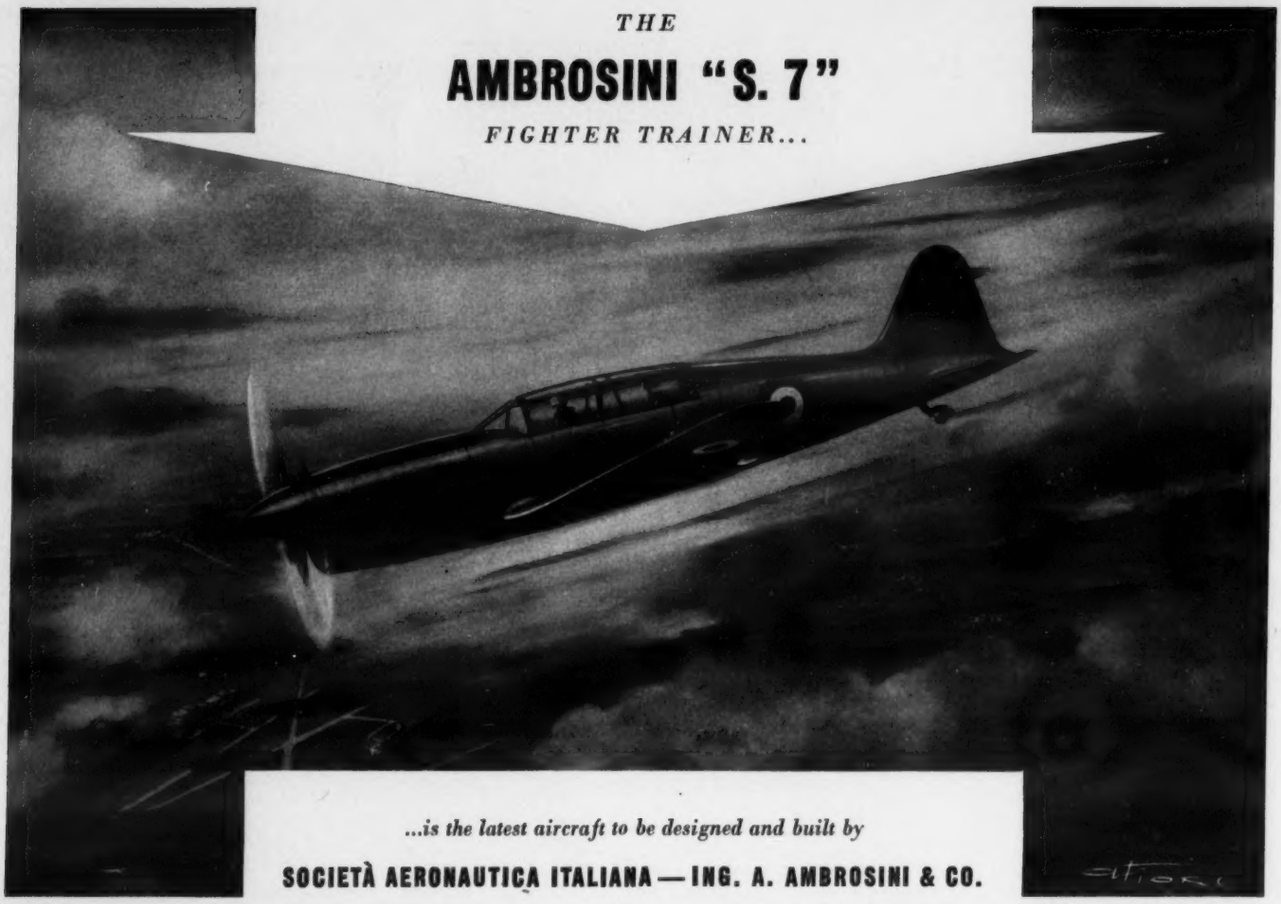

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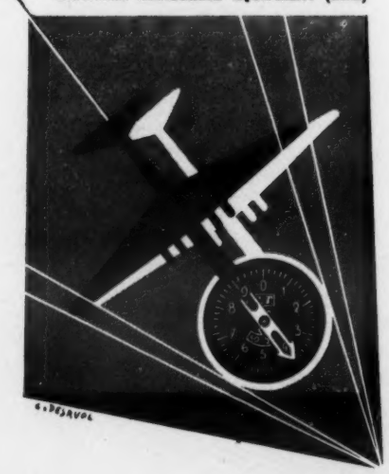

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